Sky and TELESCOPE

Bernhard Schmidt in his workshop

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Vol. XV, No. 1

NOVEMBER, 1955

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From the Life of Bernhard Schmidt

The New Schmidt Telescope of the Hamburg Observatory

World Astronauts Meet in Denmark

Axial Rotation and Stellar Evolution

Jodrell Bank Symposium on Radio Astronomy

Stars for November

Sky and TELESCOPE

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Vol. XV, No. 1 NOVEMBER, 1955

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COVER: The inventor of the coma-free reflecting telescope, Bernhard Schmidt (1879-1935), is here seen at work in his shop in the basement of the Hamburg Observatory, at Bergedorf, Germany. The picture was taken in 1928. (See page 4.)

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FEATURE PICTURE: The North America nebula in Cygnus, NGC 7000, photographed by Bernhard Schmidt on December 21, 1932, with his newly invented coma-free reflector. The exposure time was 1¼ hours at f/1.75. Hamburg Observatory photograph 6

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Lunar Mountain Heights

THE MOON is receiving increasing attention from both amateur and professional astronomers, as our satellite now seems less remote and unapproachable than it did a few years ago. There is new interest in the precise mapping of the moon, and with this in the measurement of the relative elevations of points on the lunar surface.

Basically, finding the height of a mountain on the moon consists of measuring the length of the shadow that it casts. Then, as the altitude of the sun as seen from that mountain is known, the height is simply calculated. In the middle of the 19th century, many heights of mountains and crater walls were determined by J. Maedler, and especially by J. Schmidt, who measured the shadow lengths with micrometers attached to small telescopes. Surprisingly, we have had little information beyond these rather rough observations, which are still quoted today.

Recently Dr. G. Schrutka-Rechtenstamm, at the Vienna Observatory, has published a catalogue of the altitudes of some 160 points, mostly near the central part of the moon's disk. He used the Paris photographic atlas of the moon, in which the moon's diameter is over three feet, ample enough to allow the shadow lengths to be read off with a millimeter scale. Usually, each peak could be measured on two different pictures in the Paris album. Furthermore, in many cases Dr. J. Hopmann also determined the heights from visual measures of the shadows with Vienna's 27-inch refractor.

The highest peak in this list is Calippus α, now found to tower 19,400 feet (5,900 meters) over the lower land to its east. (On one of the two photographs from which it was measured, its shadow was 1.2 inches long, for a sun elevation of 9.3 degrees.) The early figure by Schmidt was only 14,400 feet. Although there are higher mountains on the moon, up to nearly 30,000 feet in cases, these are reported for the most part near the limb.

The photographically determined heights of lunar mountains come out slightly greater than those found visually. Clearly some systematic errors affect one or the other method, and the combined result of the two procedures may be best.

The length of a shadow depends also on the configuration of the surface upon which it falls. In large-scale motion pictures of the advance of a shadow across a crater floor, even minute relief is betrayed by a hastening or retardation of the shadow's progress. Observations of this effect have been attempted only once, when about 20 years ago observers at the McMath-Hulbert Observatory mapped the interior of the crater Theophilus in this way. The experiment would be interesting to repeat. J. A.

FROM THE LIFE OF BERNHARD SCHMIDT

A. A. WACHMANN, *Hamburg Observatory*

IF YOU were to form a picture of Bernhard Voldemar Schmidt as his contemporaries saw him, and perhaps had to see him, it would be a caricature of the real Schmidt, both as an optical artist and as a man. Although he was at times attracted by other people—and there were many who thought they knew him well—basically he recoiled from them.

"Only one man alone is worth anything. Put two men together and they quarrel. A hundred of them make a rabble, and if there are a thousand or more, they'll start a war." This, in his own words, was his attitude to his fellow men.

From this attitude resulted a rather peculiar, word-sparing, and shy man, by nature even disobliging and inaccessible, who faced life alone. This explains why we have no systematic accounts of his life, and why he never personally instructed others in the making of optical instruments, an art that he had developed to the utmost. He resisted repeated appeals to preserve in writing his professional experiences, saying: "Let the others collect that experience themselves. If I were to write it down, it would so shock the astronomers and the opticians that I'd probably never get another order to construct anything."

And thus we are left in the dark as to how he actually arrived, after one false start, at his great invention in 1929 of the coma-free reflecting system.

If he was this reticent about professional matters, he was even less communicative about his youth and career. His surviving brother gives us some reminiscences of their youthful days together at their birthplace on the Estonian island of Nargen. "He was a person of very, very few words. In his youth, among other children he was rather shy, often lost in thought, but always busy with something interesting." This is perhaps the fundamental reason that his strongly individualistic personality has become so wreathed in legend and anecdote during the 20 years that have passed since his death.

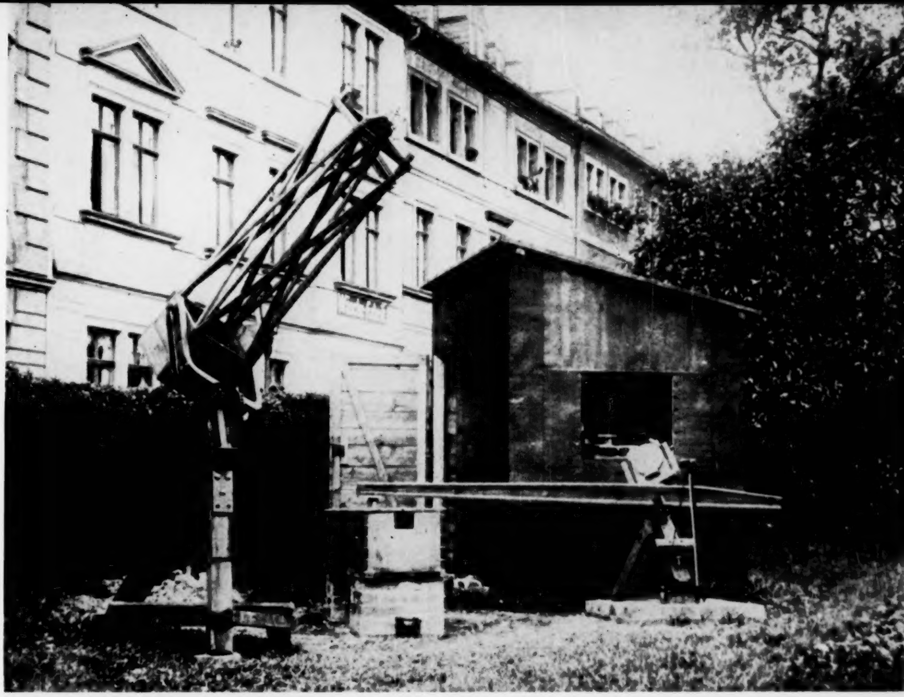
Here I shall not attempt to give the whole life story of this man who rose to such importance wholly by his own efforts. To us astronomers, it is most apropos to ask how Bernhard Schmidt probably began to make optical parts of astronomical instruments. The persistent tale that he found the bottom of a broken bottle on the beach of his native island, and ground it into a lens with sea sand, is almost too good to be true. But it is likely that, after the unlucky experiment with explosives that cost him his right forearm, he found leisure in 1895 to follow his astronomical and optical bent, when at the age of 16 he became a night telegraph operator for the coast guard station at Reval.

He must have used his free time for these pursuits later, when he was a photograph retoucher, and when in 1898 he started work for the Volta firm, which manufactured electrical instruments. For example, there is frequent mention of his name in the *Astronomische Rundschau*, a rather obscure periodical, now long extinct. Some passages in it indicate that as early as 1899 Schmidt was concerned with optical problems, specifically with fluid lenses. Characteristically, his first encounter with astronomers was an unorthodox one.

Bernhard Schmidt, as he looked in 1930, when he was making the first coma-free reflector. This picture and the other illustrations with this article were supplied by the author, to whom all publication rights are reserved.

The advice of the editor of that magazine sounds strange, in view of the tremendous advances that Schmidt was later to make in astronomical optics. "You would do better to buy an ordinary objective, for a 2-inch performs better than

The location of Schmidt's workshops in Mittweida, Germany, is at Nos. 15 and 17 on this map, which also includes several eating places, his dwelling (left center) and observatory (upper right).



Schmidt's observing station in Mittweida, as it appeared about 1920. A Cassegrainian reflector and part of the horizontal telescope are seen.

your 5-inch." We can probably assume that this 5-inch was the first telescope Schmidt ever made. In any case, it is certain that by this time he was enthusiastically observing the sky, for he is repeatedly named as an observer in the *Astronomische Rundschau*, and as one of the numerous discoverers of the famous Nova Persei in 1901.

Toward the end of that year, at Mittweida near Jena, Schmidt systematically began to grind small mirrors. There he studied engineering for several semesters, after a short visit to the Chalmers Institute at Gothenburg, Sweden. He had to grind the mirrors in his boardinghouse room, and on top of a polished chest of drawers. His otherwise friendly landlady objected to such disrespect for a worthy old piece of furniture, and threw him out. So he went to work in unfurnished rooms and finally in a deserted bowling alley, which might be called "The Bernhard Schmidt Optical Works."

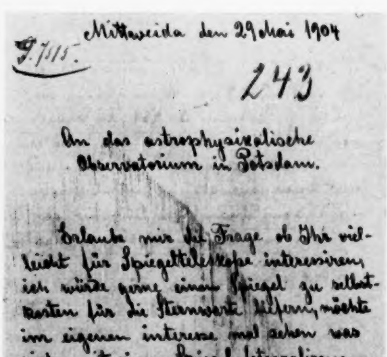
The map shows the location of his workshop and observing site, and other important buildings at Mittweida. Is it really coincidence that the path from workshop to observing station leads through the Lindengarten restaurant? The proprietress there, now very elderly, writes me, "He used our tavern day and night, and would run out quickly time and again to observe. He would request, 'Put out a bottle of good brandy for me, and if as I go by I pour myself some, then I'll make a mark on the beer mat.' We used to make out very well with him." Schmidt called this "raising his potential energy."

It was the parabolic mirrors of up to 20 centimeters diameter produced in this workshop that made his name famous in amateur circles. At that time of rivalry between refractors and reflectors, we read in a magazine (1903): "Mr. Schmidt has recently tried to remove trial and error from the process of grinding, and by a systematic procedure to generate a paraboloid directly. His method is almost mathematical in its reliability. In any case, the mirror surface must be made at least twice as accurate, since a small surface error has about three times as much effect as with an objective [lens]. This probably explains why hitherto so few good mirrors have come into the hands of astronomers."

And further, "The artist Bernhard Schmidt has certainly achieved a tour de force, for he gave one mirror the remarkable focal ratio of f/5. He has earned the highest praise, if he can give such perfection to so short a reflector."

Since Schmidt's parabolic mirrors were enjoying great favor with the amateurs, he felt that it was time to approach the professional astronomers. So he wrote on May 29, 1904, to the Potsdam Astrophysical Observatory: "Permit me to ask whether you are interested in reflecting telescopes, for I would gladly provide a large mirror for the observatory at my own cost, so that I could find out what a large mirror can do photographically after it is mounted."

From this first contact with astronomers developed a close relationship with the Potsdam Observatory, for both H. C. Vogel and K. Schwarzschild, the directors in his time, immediately recognized his genius in making fine optical surfaces. This is clear from their correspondence, which has been preserved in full. With



Mittweida den 29 Mai 1904
J. 7115.
243

An das astrophysikalische
Observatorium in Potsdam.

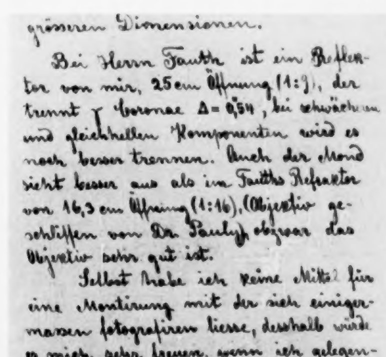
Erlaube mir die Frage ob Sie viel-
leicht für Spiegelteleskope interessiren,
ich würde gerne einen Spiegel zu selbst-
kosten für die Sternwarte liefern, möchte
im eigenen interesse mal sehen was
sich mit einem Spiegel fotografiren
lässt, wenn es montirt ist. Beifolgend
ein Mondbild mit einem 50 cm. Spiegel
(Öffnungsverhältn. 1:10), und Sternspuren
mit ein 38 cm Spiegel (1:4), beide bei
voller Öffnung aufgenommen. Montirung
primitives Holzgerüst. Visuell garantire
ich gleiche Definition wie ein Refrak-
tor von gleicher Öffnung, auch bei

This is Schmidt's letter to Potsdam in 1904, part of which is translated in the text. Schmidt says further:

"Enclosed is a picture of the moon with a 50-cm. mirror (focal ratio f/10) and star trails with a 38-cm. f/4 mirror, both taken at full aperture, on a primitive wooden mounting. Visually, I guarantee the same definition as a refractor of equal aperture, even in larger sizes.

"Herr Fauth has a 25-cm. f/9 mirror of mine, which splits γ Coronae, separation 0.54 second, and it does even better on fainter double stars which have equal components. Also, the moon is seen better than in Fauth's 16.3-cm. f/16 refractor, whose objective was figured by Dr. Pauly, although that objective is very good.

"I myself have no means for making a mounting that will allow some photography, and therefore I would greatly appreciate an opportunity to mount a reflector, perhaps by attaching it to the tube of a telescope."



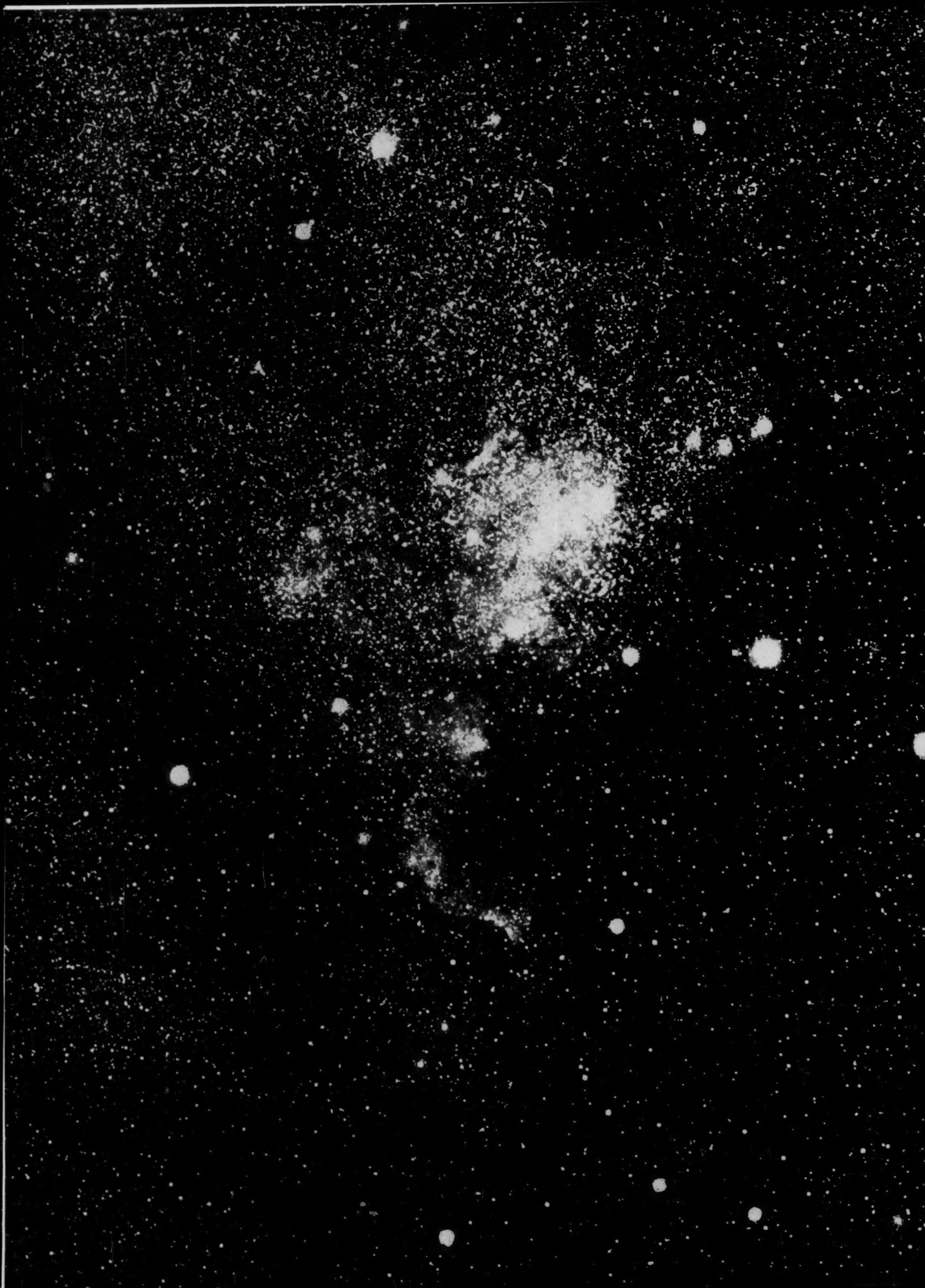
grösseren Dimensionen.

Bei Herrn Fauth ist ein Reflek-
tor von mir, 25 cm Öffnung (1:9), der
trennt γ Coronae Δ = 0,54, bei schwächern
und gleichhellen Komponenten wird es
noch besser trennen. Auch der Mond
sieht besser aus als im Fauths Refraktor
von 16,3 cm Öffnung (1:16), (Objectiv ge-
schliffen von Dr. Pauly), obzwar das
Objectiv sehr gut ist.

Selbst habe ich keine Mittel für
eine Montirung mit der sich einiger-
massen fotografiren liesse, deshalb würde
es mich sehr freuen, wenn ich gelegen-
heit bekommen würde ein Spiegel auf-
zumontiren, vielleicht indem man an
ein Fernrohr festschraubt.

Um gütige Antwort bittet
Hochachtungsvoll
B. Schmidt

(Schützenstrasse 37 [illegible])



his own hand, Schmidt made a series of mirrors down to even f/2.5, whose performance was widely praised, and concerning which Vogel wrote to Schmidt, "I am delighted that you have fulfilled the stated specifications in so complete a manner."

In these letters one finds a wealth of interesting information on new grinding methods, testing of flats by interference fringes, and considerations on technical constants, which are too lengthy to be covered here. The same must be said of the history of the great Potsdam telescopes, but Schwarzschild reports that Schmidt changed the 50-centimeter objective from a bad one into an outstanding one.

The influence with the government of the original manufacturer of the 80-centimeter objective, R. Steinheil, hindered Schmidt from trying similarly to refigure that lens, despite Schwarzschild's strong recommendation. The latter wrote, in his characteristic and trenchant way:

"Only outstanding artistry can make appreciable improvement in the 80-centimeter objective. My confidence in the quality of Schmidt's work is based not only on his artistry, but also on his extraordinarily clear insight into the mathematical principles of telescope optics, which he as a self-trained man has developed for himself. Moreover, there is a much greater prospect of an early completion of the job. This is because Mr. Schmidt is an independent man who puts his entire energy into his work without relying on outside help. Objectives are works of art, and should be compared with works of art. There is the same difference between a Rembrandt painting and a painting from the school of Rembrandt as there is between an objective made by a master and an objective that comes out of a workshop."

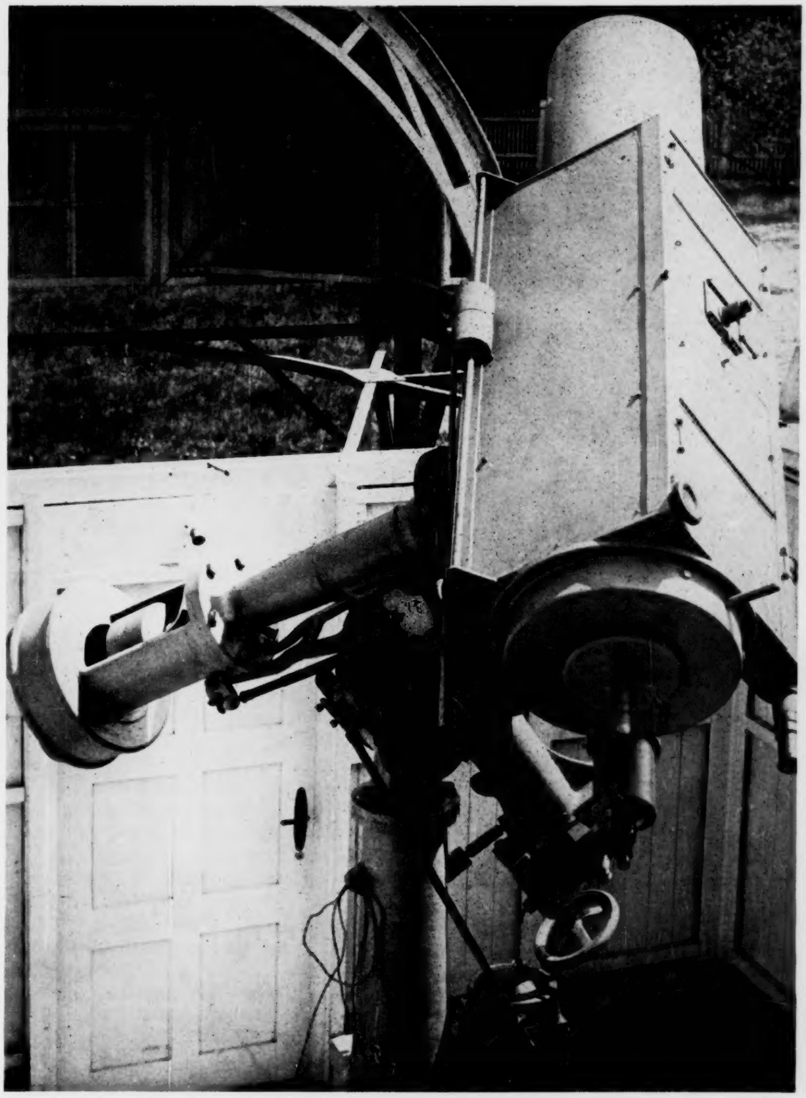
An all-too-shortsighted government resisted these words and decided against the master.

Schmidt's independence was, however, once endangered. In a letter from the Goerz optical works, dated August, 1911, we find, "We take this opportunity to inform you that Schmidt's optical shop in Mittweida is now affiliated with our organization." How Schmidt escaped from this connection is unknown to me. But if this free man with his irregular working hours had been tied to an "optical treadmill," as he himself termed it, perhaps we would have no Schmidt telescopes today.

The fruitful relations with Potsdam broke off with the contract to Steinheil for refiguring (to the disadvantage of the 80-centimeter objective), and with Schmidt's temporary internment as an enemy alien during World War I. This is the place to destroy the legend of Schmidt's German ancestry, which is repeated in all accounts of the man, in Germany and abroad. The name Schmidt, not exactly rare among Germans, was assumed by an ancestor of Bernhard Schmidt, named Matts, at a time when the few Germans in the Baltic countries formed a ruling class, and when it was customary to borrow such a name. So the Estonian Matts became a Schmidt, but not a German.

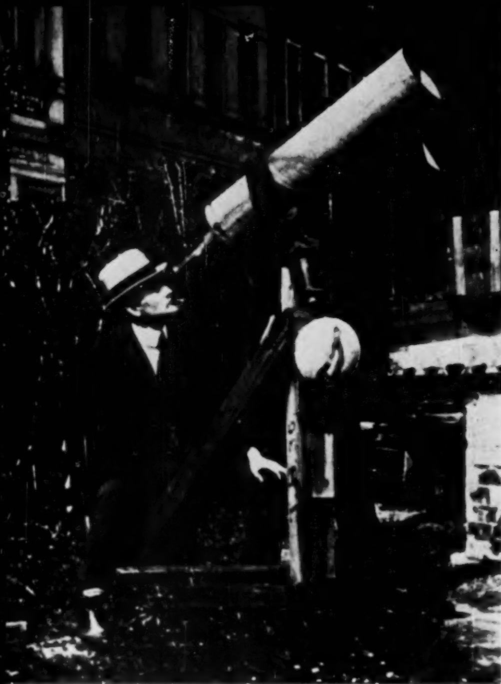
With grim humor, Schmidt would sometimes tell about his war experiences in a prison camp, and later in Mittweida under police surveillance. Schmidt's favorite instrument, his horizontal reflector, came under suspicion of the police, who thought that it was being used to flash light signals to Russian aircraft. This horizontal telescope consisted of a siderostat, with an effective hydraulic drive that was as ingenious as it was absurdly simple, and parabolic mirrors of 11 to 31 meters focal length.

A great collection of very beautiful photographs of sun, moon, and planets, testifies not only to the quality of the instrument, but to the high observing skill of Schmidt, whose great persistence



The first Schmidt telescope, with which the facing photograph was taken. It contains a 17.3-inch spherical mirror of 24.6-inch focus, and a correcting plate 14.2 inches in diameter, giving sharp images over a field 15 degrees across.

FACING PICTURE: The North America nebula in Cygnus, as photographed by Bernhard Schmidt on December 21, 1932, at Hamburg Observatory with the original Schmidt camera. This instrument was the greatest innovation in astronomical optics in two centuries. Through an ingenious elimination of optical aberrations, a Schmidt camera combines large light grasp, sharpness of images, and wide field to an unrivaled degree.



Here Bernhard Schmidt is seen at the eyepiece of a Cassegrainian reflector, at his Mittweida observatory in 1921.

and knowledge of atmospheric conditions particularly aided him. Through an unusual device, the barbaric deformation of the optical flat by the pressure of a screw, he succeeded in completely eliminating at the center of the plate the astigmatism caused by the oblique orientation of the flat.

This horizontal telescope gave him experience, confidence, and fresh initiative. On March 12, 1916, he wrote to Prof. R. Schorr, then director of the Hamburg Observatory, "Allow me to send you some astronomical photographs that I have recently taken here at Mittweida." After a short description of his optical system, he continues, "Also let me ask whether you perhaps have astronomical optics to be refigured, old object glasses or the like. I can now produce at will objectives to technical constants of 0.1. If you have any further interest in this, I am prepared at any time to furnish details."

These exceptionally fine pictures completely convinced Schorr, and in October, 1916, Schmidt received an order to build an identical horizontal telescope for Bergedorf. What the Army Command had denied him as an alien during the war was granted to him by the Workers and Soldiers Council during the revolution days of November, 1918: Schmidt's first visit to Bergedorf, to erect the new telescope. Perhaps he would have settled there permanently then, if the financial crisis of Germany and hence of the observatory had not been so formidable.

Even though this situation produced a grave crisis for his workshop as well, he turned down an opportunity to emigrate to Holland.

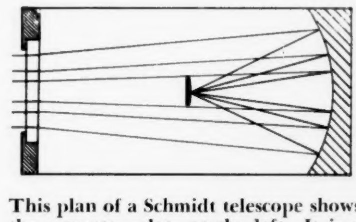
"Your invitation to Holland is very kind, but I have no idea what use I would be to your country, as I could operate neither as a factory owner nor as an independent craftsman. Here in Germany astronomy has dropped into the background, and since there is nothing especial to do in astronomical optics, I have recently taken up periscope problems. With periscopes made on my plan for use in closed passenger planes to observe the ground beneath, I have obtained fields of view up to over 100 degrees with images sharp to the edge."

Several patent applications followed, and there were negotiations with the Junkers aircraft works on the practical use of his invention. Developments in aviation were too rapid, however, for him to make a financial success of his idea. The same fate befell his patent of 1926 for a flexible optical system, familiar to the medical profession as the gastroscope; Schmidt's connection with it is hardly known.

The optician escaped the effects of the inflation of 1923 by a stay in his native Estonia. In January, 1924, he wrote to Schorr, "When the dollar got to be worth more than a million paper marks, I felt that I had better get outside of Germany. I would have had more opportunity there, but what could I have done with the worthless billions and trillions? But since the new marks seem to be remaining stable, I plan to return to Mittweida. I have gotten some foreign orders and must get back to Germany to fill them."

This hope was deceptive. In April, 1925, Schmidt was discouraged: "Since I got back, not a single order has come in. I'm ready to turn my whole stock into junk and sell it for old iron and charcoal, and then take up something new." But he was diverted from this step by Prof. E. Schoenberg, of Greifswald, who purchased his horizontal reflector. At Greifswald a new technical problem engaged him.

"I am now working on problems of sailing ships and am deeply involved in practical matters. Among other things, I have hit on an idea like Flettner's. I have devised a horizontal rotor, in propeller form, which needs no auxiliary motor and which actually works best with a head wind, when Flettner's rotor is really very inefficient. With my arrangement, I have even found it possible to sail by wind power alone straight into the wind, at no great speed, but I can get there faster than an orthodox sailboat can by tacking.



This plan of a Schmidt telescope shows the corrector plate at the left. It is a thin aspheric lens that slightly deviates all entering light rays, in order that the spherical mirror (right) may bring them to a focus without aberrations. The focal surface is convex to the mirror. The corrector plate is placed at the mirror's center of curvature.

"Nobody, however, believes that I can sail against the wind, and people ridicule the idea as if it were perpetual motion. To go against the wind I use a fast-running light wind turbine that drives a water propeller, but it's a ticklish problem to construct the propeller so that it overcomes the greater back-pressure of the turbine."

There is in existence an extensive manuscript in which Schmidt traces the entire theory of his ship. But again, a patent application led to nothing. A letter expressing his resignation with "windmill engineering," as he called it, ends, however, with a gleam of hope for astronomical optics. "By any chance do you have anything for me to do in Bergedorf? Recently I have been trying out a new mirror combination, a kind of unperforated Cassegrain with complete elimination of coma and astigmatism." This is the first indication of the great problem which was from now on to occupy him.

Following Schorr's invitation, toward

In June, 1935, six months before Schmidt's death, he and the author of this article (Dr. A. A. Wachmann, right) conversed about the air-propeller invention.

the close of 1926 Schmidt began his activity at the Bergedorf Observatory as a volunteer staff member. Now he had not only the facilities of a large institution at his disposal, but the steady encouragement of Dr. Schorr, who kept him busy with optical and delicate mechanical construction work.

A glance into his workshop in the basement of the main building would reveal not only his industry but his genius at getting astounding results from apparently primitive means. Few people managed to enter there, where he worked at any hour of the day or night. If, however, he accepted you, and if you were content to watch in silence as you smoked, then you saw the true artist at work, served by a workshop (front cover) of whose peculiarities he was fully master.

You would watch his steady concentration upon the piece he was working, and you would be astonished by the almost uncanny certainty with which he always knew the right moment to break off polishing to test the optical surface, whether with an artificial star or by interference fringes. Perhaps the real secret of his success lay in this, and in the ability of his practiced eye to detect the least deviation of the surface from the ideal figure. Clear reasoning and long years of experience at once told him how and by what amount these deviations were to be corrected. You would wonder at the delicacy of touch of his left hand, the only one he had. Schmidt himself said, "My hand is more sensitive than the finest gauge," and when someone during his absence had playfully given the polishing tool a few strokes, he said at once, "Somebody has been fooling around with this."

He objected to polishing by machine. "The machine makes mistakes, because the epicycles the tool traces require mathematically that the zones aren't all treated alike. If the hand encounters friction, you have to stop work at once until the temperature is evened out. But your machine can't detect this; it polishes on mindlessly, warming up the place of the friction, and your defect gets bigger and bigger."

Another time he said, "In figuring a defective surface, it's better to start with the central zone than at the edge. A mirror that is polished by radial strokes alone is going to show not diffraction rings but showers of sparks."

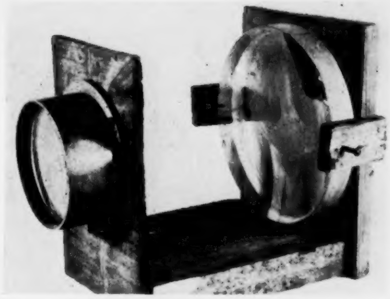
With these aids and in this setting, he put his great idea into practical form. Here was made the world's first Schmidt telescope, with the unheard-of focal ratio of f/1.75, which photographed the sky with a previously unknown sharpness that is now everywhere associated with the name of Schmidt.

It is astonishing to say the least, and also shameful, that despite loud praise for this revolutionary invention, and despite the very low delivery price of 5,500 marks, not a single final order was placed! Negotiations with a Russian importing agency were stalled by foreign-exchange difficulties, and another order from Goettingen fell through.

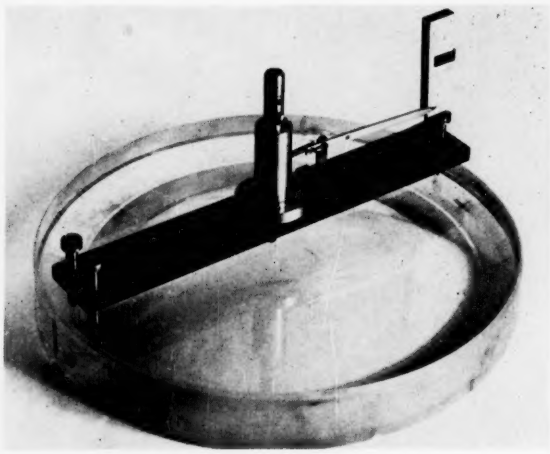
Nevertheless, his Estonian stolidness, and his attitude toward men in general and astronomers in particular, carried him through this bitter disappointment. At times he spoke very bitingly, and if he had been drinking—*auf Achse,* he used to say—he would order another round for everybody and tell them prophetically, "The whole world is going to hear of Schmidt some day!"

It was a deep tragedy, an inventor's fate, that Bernhard Schmidt never lived to see the astonishing spread of his coma-free telescope after 1936, when Schorr lifted the secrecy from how its correcting plate was made.

Yet disillusionment did not prevent Schmidt from attacking further problems. For example, there is the design of a field-flattening lens to be added to the original Schmidt telescope. He anticipated increasing the focal ratio to f/1, and, even more, that a lens system would be better than a correcting plate. He made detailed calculations for this, and made a first model, a typical wood-and-screw assembly of his which, despite its primitiveness, in the artist's hands took good photographs.



In 1934, Schmidt tested the components of his achromatic lens-mirror system in this wooden mounting.

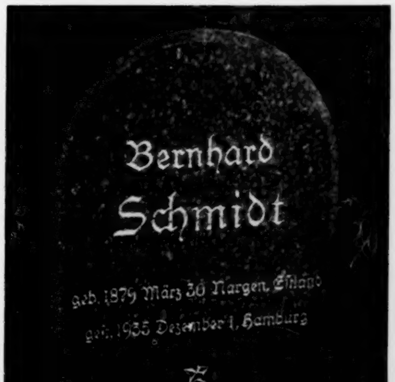


Schmidt made a series of spherometers which he used for the rough testing of optical surfaces. This is a beam type, which contains a scale at the right end, where the settings are indicated by the long pointer arm connected to the central post.

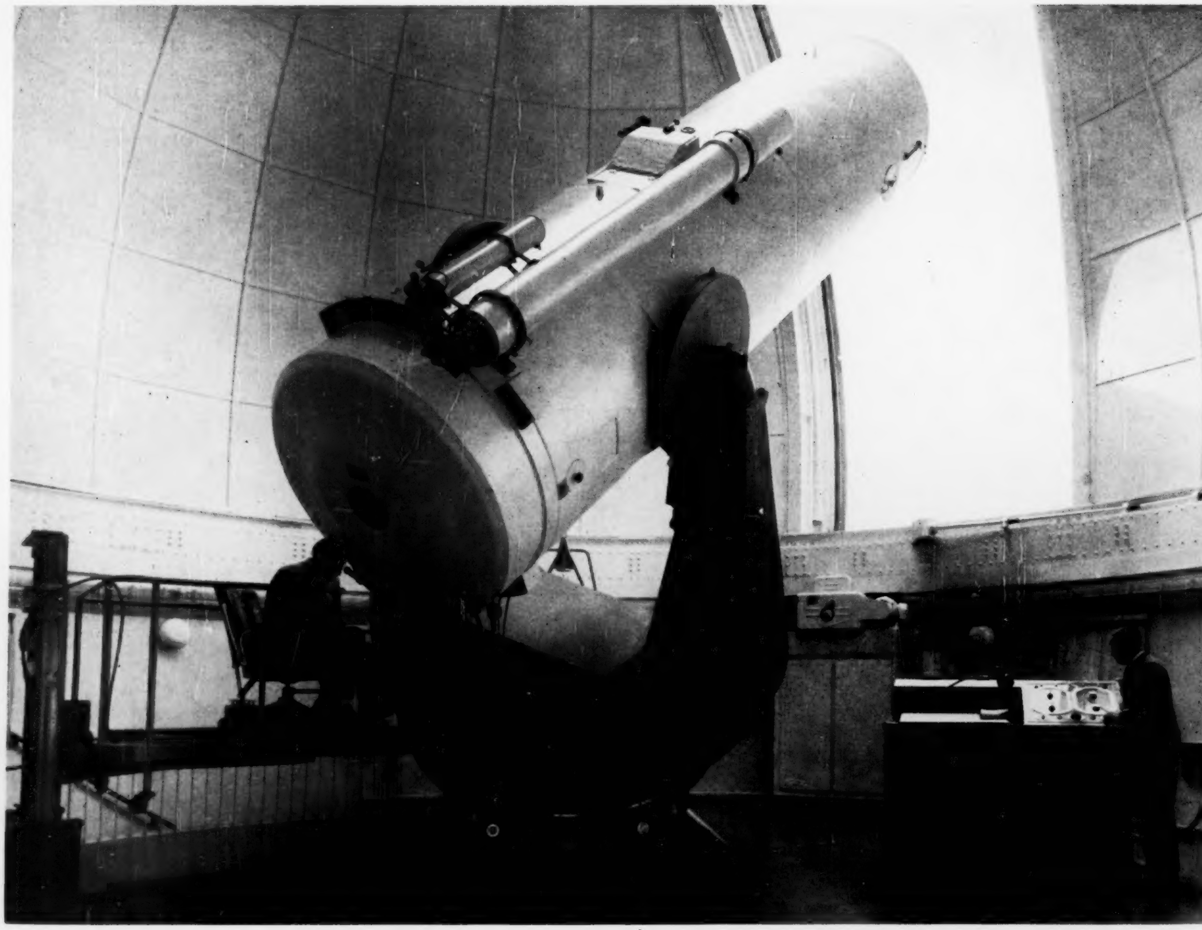
Up to the last he retained interest in his old windmill problem, which he had extended into three dimensions. With unceasing enthusiasm, he worked with propellers having various angles of attack, which he attached to broomsticks, to study their behavior during ascent and in the air. These experiments were for the development of a windmill glider.

His last project was a special reflecting system: a 60-centimeter, f/2 spherical mirror, from which light passed through a pair of perforated lenses, the back face of one of which was silvered to form the secondary mirror! Then death took the polishing tool from his hands, 20 years ago this December.

Twenty years can change a world, but they have not dimmed the fame of a remarkable man, the greatest optical worker of our century, Bernhard Schmidt. Despite the passage of time, mirrors of high optical perfection and of the greatest astronomical significance will always remain associated with his name.



The optician's grave.



The new Schmidt telescope, seen here from the north, has a distinctly modern appearance. The principal supporting unit, with two oil pad bearings, protrudes from the floor in the middle foreground. The preset and control panels are in a desk (right) that may be moved to any convenient place on the observatory floor. At the left is the electro-hydraulic jack that carries the observer's platform. Midway along the upper side of the telescope tube is the cover of the opening through which the plateholder is inserted. Hamburg Observatory photograph.

The New Schmidt Telescope of the Hamburg Observatory

O. HECKMANN, *Hamburg Observatory*

EVEN BEFORE World War II, it had been planned to modernize the Hamburg Observatory (located at Bergedorf, a suburb of Hamburg, Germany) by the addition of a large Schmidt-type telescope. But funds obtained at that time were completely depreciated as a result of the war, so the project had to be started afresh.

In 1947 we began design of the instrument, and in 1949 the first appropriation for the purpose appeared in the budget of the Hamburg state government. Work has progressed steadily, and the new instrument was dedicated on August 19-20, this year. The occasion provided an opportunity for an international gathering of more than 150 astronomers, who heard a symposium on Schmidt telescopes and their uses. One of the papers, by Dr. A. A. Wachmann, concerned the life of Bernhard Schmidt; it forms the basis for the article on page 4 of this issue of *Sky and Telescope*.

Before the war we had been thinking of an instrument with a correcting plate 80 centimeters (31.5 inches) in diameter,

a mirror of 100 centimeters, and a 160-centimeter focal length. For the new project, however, we chose 80, 120, and 240 centimeters, respectively, giving a focal ratio of f/3.

The contract for optics and tube, which form an integral unit, was given to the firm of Carl Zeiss, in Jena. The mounting was built at Hamburg in the machine shops of Heidenreich and Harbeck, under the supervision of Dr. Walter Strewinski. Co-operation between the two firms was excellent, even though Hamburg and Jena lie in two politically different parts of Germany. By the fall of 1954, the assembly of the instrument was substantially complete, and last winter and spring we could check its operation in detail.

The mirror is made of ZK7 Schott glass, which has a rather small coefficient of thermal expansion, even though it is higher than that of pyrex glass. The back side of the mirror has been ground convex, so the mirror is bounded by two concentric spherical surfaces. This should provide more thermal homogeneity than with a mirror having a flat back and thick edges.

The correcting plate was made from UBK7 glass, which transmits ultraviolet light well. The same material was chosen for an objective prism with a four-degree refracting angle. This provides a low dispersion of about 570 angstroms per millimeter at the wave length of the hydrogen-gamma line.

Originally we had planned to bend the correcting plate into a meniscus shape, to lessen the often very undesirable reflections from the plate. This idea ran into serious difficulties during manufacture; consequently, the outer face of the correcting plate is plane, while the inner surface has the well-known profile of the Schmidt corrector. The least thickness of the correcting plate is at a distance of 0.87 of its radius from the center, thereby minimizing chromatic aberration. For the time being we must put up with the ghost images, but eventually we hope to coat the plate or replace it by a meniscus-shaped one.

We tested the optics carefully in the laboratory and later on the sky. The circle of confusion, inspected visually, is about 0.5 second of arc in size; unsteady air and the diffusion of light in the photographic emulsion will naturally make the star images larger than this. With very good seeing, the smallest star images are about 0.025 millimeter in diameter.

The telescope tube is double-walled, to avoid flexure when we use the heavy objective prism, which with its cell weighs about 880 pounds.

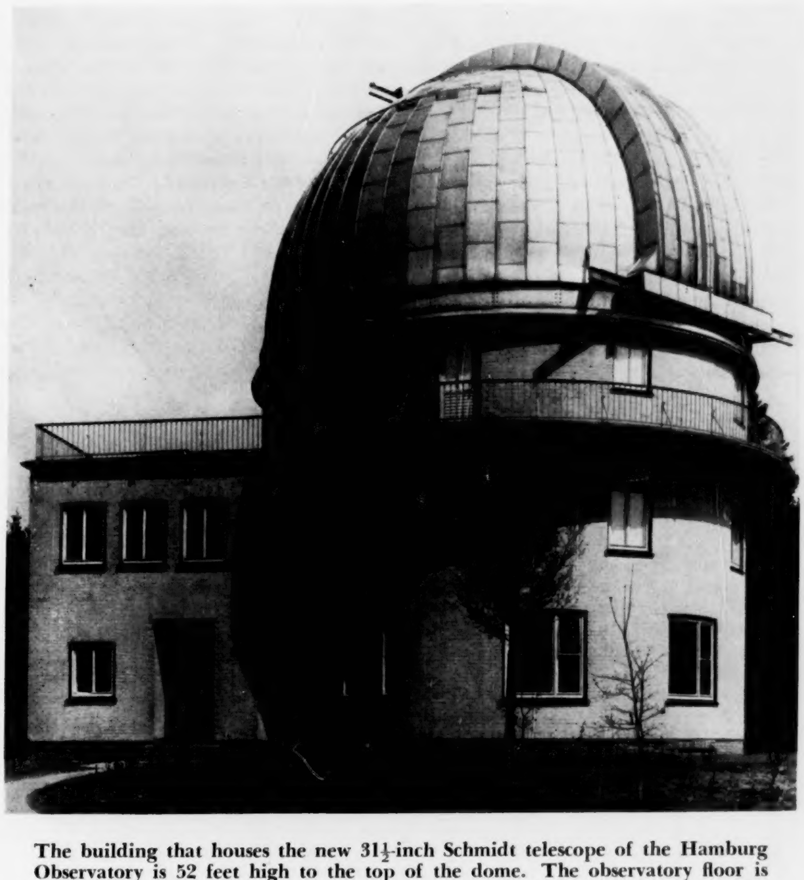
As with the 48-inch Palomar Schmidt, there is provision for an automatic compensation for focus changes due to temperature. Three rods, whose linear coefficient of thermal expansion exactly corresponds to that of the mirror, serve as spacers between the mirror and plateholder assembly. The latter is fixed in the tube, and the mirror therefore "floats"; it rests on a system of 24 counterpoises, and can be displaced along the optical axis. It can even be tilted, but not shifted perpendicular to the optical axis.

Since the spacer rods would respond to temperature more rapidly than the mirror would, the rods are each made in two parts. The longest part is of invar steel, whose thermal expansion is practically zero. The other part is a special, rigid plastic of high expansion coefficient, and is in close surface contact with the edge of the mirror, responding accurately to temperature changes in the mirror. In this way, there is no appreciable time lag between slow thermal changes of the compensating rods and of the mirror. Naturally, care must be taken that rapid changes in temperature do not occur inside the tube.

For this reason the whole tube was covered with felt, over which canvas was stretched and then painted. The cork-lined dome has good thermal insulation. Rapid outdoor temperature changes are reduced inside the dome to about one third of their amount, and inside the tube to less than one fifth. Therefore, only slow temperature changes affect the mirror, and for these the compensation system works well. Through the past winter and summer, we have found no change in focus amounting with certainty to 0.05 millimeter, although the temperature ranged through 30 degrees centigrade (more than 50 degrees Fahrenheit).

As with other Schmidt telescopes, the focal surface is located midway between the correcting plate and the mirror, and it is curved convex to the mirror. Our plates are 24 by 24 centimeters square, covering an area of the sky five degrees on a side. The spherical template which is pressed against the back side of the plate is covered with a very thin rubber sheet, which takes up the tangential stresses caused by friction when the plate is bent. With plates one millimeter thick, breakage occurs only when a plate remains more than 24 hours in the plateholder.

Since the plates are originally flat, they cannot take up an exactly spherical form



The building that houses the new 31½-inch Schmidt telescope of the Hamburg Observatory is 52 feet high to the top of the dome. The observatory floor is level with the exterior observing deck. The ground floor houses four office rooms and two smaller laboratories, each of which contains a photometer. The second floor contains three darkrooms and the aluminizing laboratory. The dome is 36 feet in diameter, and the shutters open to provide a slit 10 feet wide. An elevator in the northern part of the building permits moving heavy parts and equipment from one floor to another. Hamburg Observatory photograph.

when they are bent. Over a central area about three degrees in diameter, a plate fits well against the template. There is then a region about one half to one degree wide where the plate may deviate up to 1/20 millimeter from the sphere, and at the edge the plate is again firmly pressed against the template. In very precise photometric and astrometric work, corrections have to be applied in the said region, but average corrections can be used, as they do not exceed 0.05 magnitude or 0.003 millimeter.

The plateholder is inserted through an opening in the tube by means of a carriage, to which different color filters can be attached as well. After it slides along a rail into the interior of the tube, the carriage is screwed firmly against three supports. The weight of the carriage, when loaded with the plateholder, is compensated by a long spiral spring at the side of the tube opposite the opening, so the plateholder carriage is inserted without effort.

There is an electrically driven venetian-blind type shutter, located in the carriage and going around the inserted plateholder.

The two guide telescopes are fastened to the main telescope tube in such a way that no appreciable relative flexure occurs. Only one of these guide telescopes is seen in the photograph of the instrument, but the observer in the chair is looking through the eyepiece of the other. The plateholder can be focused electrically from either guide telescope.

Behind the mirror are ventilators to equalize the air temperature in front of and in back of the mirror, and at various points inside the tube there are thermostats to control the thermal state of the instrument. We have had no time and fortunately no necessity to test these arrangements.

The mounting of the instrument is of the fork type, following the example of the 48-inch Palomar Schmidt—this type is particularly appropriate for conventional Schmidt telescopes. A new basic idea has been incorporated at the suggestion of Dr. Strewinski. In the diagram imagine a sphere drawn around the center of gravity (*C*) of all moving parts of the instrument; a portion of this sphere is marked by the dashed curve. Concentric with the polar axis, a zone (*Z*) of this sphere has been constructed as a bearing of steel. This bearing rests on the vertical steel pier (*P*) directly beneath the center of gravity, and turns on two oil-pad bearings (*O*) that support the entire weight of the instrument.

By this arrangement there is no weight to be supported at the lower end of the polar axis. As a consequence, it is possible to adjust the polar axis of the instrument without appreciable work against gravity. Naturally, the lower end of the polar axis must be suitably restrained in position by an adjustable ball-bearing assembly.

Thus, the telescope turns in hour angle on bearing Z, which floats on the oil film produced by the oil pads. The oil enters each pad from below through a self-adjusting biconcave "lens" of steel. The oil flows out at the edges of the lens, is collected, and is fed to the pump again.

The fork arms are made of welded sheet steel one centimeter thick. The arms have internal braces, and a special lever system substantially eliminates flexure. The crosspiece or yoke of the fork, to which the arms are bolted, is very massive in comparison to its counterpart in other instruments and its flexure is extremely small—yet it is not unattractive in appearance.

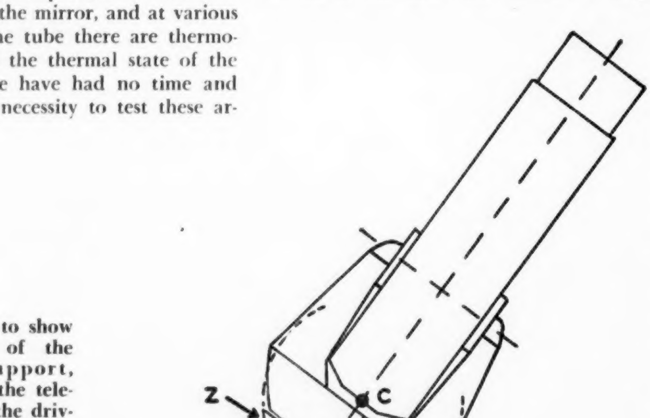
The driving gear for right ascension is located at the lower end of the polar axis. To cut the gear with sufficient accuracy, a special machine was built and used in a constant-temperature room. The divisions were transferred from a very good Wild theodolite. Careful measurements of the gear teeth with a Mikrotast gauge show that the average error of position is less than half a second of arc. Since the radius of the gear is 60 centimeters, this corresponds to an average linear error of 0.0015 millimeter. Only at a single place is the error about twice as large.

Temporarily, we are using a provisional worm gear, but we hope soon to receive a new worm that will match the high accuracy of the driving gear. The telescope's motion in hour angle is carried by a single worm for all speeds. To avoid unequal wear of the driving gear, we propose to turn the gear on the polar axis after a few years. To reduce lost motion in the right-ascension drive, a second, spring-mounted worm always engages the drive. In declination, however, the floating worm is divided into two axially symmetrical parts, held together by springs. The telescope does not have any clamps, either in right ascension or declination.

The whole instrument is electrically operated from one desk. To point the telescope at a particular heavenly object, the observer presets its position on a keyboard, to one second of time in right ascension and 1/10 of a minute of arc in declination. Then, pressing a button turns the telescope automatically into the position desired, but it is impossible for the telescope to be pointed below the horizon.

The accessibility of the guiding telescopes to the observer is increased by the portable electro-hydraulic observing platform, made by the Still Company of Hamburg. For our purposes the platform was enlarged and fitted with a convenient observing chair. The observer has at hand the electric controls for moving the entire carriage.

The platform can be removed and a heavy hydraulic support mounted on the carriage, to carry the mirror and cell from the instrument, whenever the mirror needs to be aluminized again. For this purpose, the mirror is taken by elevator to a special laboratory in the east side of the observatory building. The vacuum equipment there is on loan from the German Research Council, and was made by the Heraeus Company in Hanau. The vacuum tank has an inside diameter of 150 centimeters. The mirror is laid on a rotating table and is coated from three sources placed over its edge. Rotating the mirror guarantees uniform deposition of the coating over all parts of its surface.



In this sketch, to show the principle of the mounting support, many parts of the telescope, such as the driving assembly at the south end of the polar axis, have been omitted for simplicity. The latitude of the observatory is 53½° north. The horizontal line below the oil pads at O represents the floor of the observing chamber in the picture on page 10.

NEWS NOTES

By Dorrit Hoffleit

R. W. WOOD DIES

Johns Hopkins' renowned physicist, Robert W. Wood, for 50 years a member of the faculty there until his retirement in 1951, died on August 11th at the age of 87. His talents as an experimentalist have seldom been equaled. Recognized for both his work in physical optics and his witty literary contributions, he has been colorfully portrayed in a biography by William Seabrook (Harcourt Brace, 1941), a book that is partially a Wood autobiography.

The first edition of *How to Tell the Birds from the Flowers* was published anonymously in 1907. Perhaps Dr. Wood regretted this. He has told how it was soon attributed to another wit of the times, and he found some difficulty in getting friends to believe it was in fact the product of his own pen.

A world expert on the making of mosaic replica gratings, Dr. Wood frequently advocated their use instead of more expensive objective prisms for astronomical work in spectral classification. He made a mosaic of 4-by-6-inch gratings for use on the 18-inch Schmidt telescope at Palomar.

ASTRONOMER COMPOSERS

During the recent summer school open nights at Harvard Observatory, the visitors were entertained before each of the lectures by Miss Jean Hales, who played piano music composed by astronomers. Represented were Sir William Herschel, whose baroque organ pieces have been transcribed for piano; Dr. Ernst Opik, former director of the Dorpat Observatory in Estonia, now at the Armagh Observatory, where he is editor of the *Irish Astronomical Journal*; and Dr. Peter van de Kamp, director of Sproul Observatory, Swarthmore College.

NEW ASTRONOMER ROYAL

Sir Harold Spencer Jones, 10th Astronomer Royal of England and director of the Royal Greenwich Observatory since 1933, will retire on December 31st. From 1923 to 1933, he was in charge of the Royal Observatory at the Cape of Good Hope, where he directed fundamental investigations on the positions and motions of southern stars. His most important contribution has been the analysis of the world-wide observations of the planetoid Eros, made during its close approach to the earth in 1931, from which he derived an improved value for the sun's distance.

The new Astronomer Royal will be Dr. R. v. d. R. Woolley, present director of the Commonwealth Observatory at Mt. Stromlo, near Canberra, Australia. Besides being well known as an astrophysicist, he had extensive experience in positional astronomy as chief assistant at Greenwich during 1933-37. As successor to Sir Harold, Dr. Woolley will have as one of his principal tasks the completion of the moving of Greenwich Observatory from the suburbs of London to Herstmonceux Castle, in Sussex.

ISAAC NEWTON TREES

Although the apple tree that stood in Isaac Newton's garden at Woolsthorpe died in 1814, grafts had been taken from it, and today numerous progeny of it thrive. T. N. Hoblyn, of the East Malling Research Station, wrote to the *Observatory*, June, 1955, of recent plantings of Newton trees in various parts of the world.

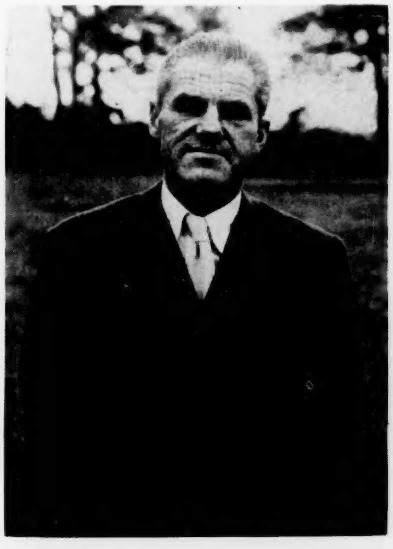
In 1944, trees from East Malling were sent to Pennsylvania for a William Penn memorial, and in 1954 trees were planted in Newton's garden at Trinity College, Cambridge, and at the Dominion Physical Laboratory in New Zealand.

STARS NOT VISIBLE FROM LONG SHAFTS IN DAYTIME

Once again the popular belief that stars can be viewed by day from the bottom of a long dark chimney or well has been refuted. Prof. Alex G. Smith, University of Florida at Gainesville, has made photoelectric and photographic measurements to show that there is no appreciable difference in zenith sky brightness within or outside a chimney 157 feet high.

In the *Journal* of the Optical Society of America, June, 1955, he also points out the accumulation of experimental data that shows the contrast sensitivity of the eye to be in fact impaired when a small luminous image (the sky at the top of the chimney) is observed in the midst of a large dark area. This is true in spite of the partial dark-adaptation of the observer's eye when he remains a while inside the shaft.

As an extra test, Professor Smith made naked-eye observations of Pollux in evening twilight at the earliest moment that the star could be seen. He found that observing within the chimney made the star a little more difficult to see in a still fairly bright sky.



The next Astronomer Royal of England, Dr. R. v. d. R. Woolley.

IN THE CURRENT JOURNALS

THE MATTER BETWEEN THE STARS, by George O. Abell, *Griffith Observer*, July, 1955. "It is known today that the material in the space between the stars is very important, and far more extensive than was once believed. It is also known to be of profound significance to the evolution of stars."

LIGHT WAVES AND LENGTH STANDARDS, by Irvine C. Gardner, *Journal*, Optical Society of America, September, 1955. "The plan to substitute a wavelength of light for the present international platinum-iridium prototype meter as a standard of length is now under consideration by the appropriate international committees."

NEW LIGHT ON THE CHANGING FACE OF MARS, by E. C. Slipher, *National Geographic Magazine*, September, 1955. "Such green areas bear eloquent testimony to the fact that Mars is not a dead world. In fact, all the various Martian markings betoken that it is a living planet, that life of some sort exists there."

WILLIAM H. CHRISTIE

A well-known former Mount Wilson astronomer, William H. Christie, died on July 13, 1955, at the age of 58. For the past decade he had been a physicist at the Naval Ordnance Test Station, China Lake, Calif. At Mount Wilson Observatory he had worked in spectroscopy and photometry, and was an authority on radial velocities and binary stars. He will be especially remembered in the Los Angeles area for his encouragement of amateur telescope makers.

ONR RESEARCH GRANTS

A call has been issued by the Office of Naval Research for proposals of research to be supported during the year ending in June, 1957. Thus, ONR will continue its modest support of basic research in astronomy and astrophysics, with the guidance of an advisory committee of seven astronomers nominated by the American Astronomical Society. Applications must be submitted by December 15th to the Chief of Naval Research, Department of the Navy, Washington 25, D. C., Attn: Code 430.

Danish delegates Erredo-Knudsen (left) and Hansen watch proceedings of the IAF congress this August. A. B. C. photo.

World Astronauts Meet in Denmark

Frederick I. Ordway, III
and Heyward E. Canney, Jr.
American Astronautical Society

As DELEGATES and observers from 20 nations in five continents converged on Copenhagen to attend the sixth international astronautical congress, world headlines announced that the United States would launch artificial earth-circling satellites, as part of America's contribution to the International Geophysical Year (IGY). The statement from Washington came only a few days before the official opening, on August 1, 1955, of the International Astronautical Federation's (IAF) annual sessions. This no doubt contributed to the close press attention given to the congress.

To the astronautical scientists gathered in Copenhagen the announcement meant that full scientific recognition had been accorded their years of calculations, planning, and labor in the field of space flight. The progression from aeronautics to astronautics had been abruptly and dramatically accelerated.

A wide range of technical papers was delivered before this year's congress, covering satellite vehicles, space medicine, cosmic ray physics, missile dynamics, the IGY, and space flight programming.

One of the most publicized lectures was given by Krafft Ehricke, representing the American Astronautical Society and the American Rocket Society. He introduced a new variation of the artificial satellite concept, a half airplane-half satellite, which he called the "satelloid." Dr. Ehricke proposed an 80-mile altitude for his satelloid, which would orbit in the tenuous but friction-producing upper atmosphere.

The satelloid would be manned, able to glide to the earth's surface, and powered by small rocket motors. These would apply thrust at intervals to maintain altitude and 17,000-mile-per-hour speed. Some 3,400 pounds of propellants would be required for a six-day observation flight. Dr. Ehricke pointed out that the relatively low altitude would be useful for determining atmospheric structure, and said that the difficulties in placing the satelloid into its orbit would be greatly reduced in comparison with the use of 200- to 500-mile altitudes.

Two papers were given by directors of the American Astronautical Society. N. V. Petersen treated the problem of determining the approximate duration in orbit for artificial satellites at various altitudes. He demonstrated that satellite lifetimes increase markedly with altitude and mass-area ratio. Factors affecting the orbital lifetime, as shown by the equations of motion, are the air density, the drag coefficient, and the earth's gravitational potential.

The authors of the present report summarized their long paper, "The Uses of Artificial Satellite Vehicles," in which it is emphasized that satellites can be essential to further development of nearly every field of scientific inquiry. The advantages of the satellite to astronomy, astrophysics, biology, medicine, physics, chemistry, geophysics, and astronautics were covered in separate chapters. It was also pointed out that the orbital base could be extremely valuable as a communications relay station, a radar beacon, a navigational landmark, and an observation platform. We consider the satellite to be of military significance principally as an observation point and a guided missiles control agency.

Alessandro Boni, of Italy, explained a technique of constraining a satellite in a circular orbit, by means of a pattern of synchronizing forces acting perpendicular to the direction of gravity. The force intensity required depends on the difference between the satellite's angular velocity and that for the circular orbit.

Another Italian scientist, G. Partel, demonstrated the advantages of launching satellite rockets from mountain stations. He selected six possible sites in the Bolivian and Peruvian Andes, served by the highest railroads in the world, pointing out that at these altitudes (12,000 to 15,000 feet) more than half of the total mass of air would be below. This would obviously greatly reduce air-drag problems. Dr. Partel also suggested possible airplane launching of minimum satellite rockets.

These are three of the principal officers of the International Astronautical Federation (left to right): president, Frederick C. Durant, III, U. S. A.; secretary, J. Stemmer, Switzerland; and vice-president, T. Tabanera, Argentina. These officers were all re-elected for further terms. A. B. C. photo.

R. Tousey, Naval Research Laboratory, considered the interesting subject of the visibility of an artificial satellite of the earth. He assumed a white spherical vehicle, 21 inches in diameter, revolving in the equatorial plane at altitudes between 200 and 800 miles. The computation of the apparent stellar magnitude of the vehicle involves the satellite's distance, its angular elevation, and its phase. Then the satellite's magnitude must be compared with the threshold magnitude visible against the sky brightness, which depends on the angular altitude of the sun.

Dr. Tousey showed that if one knows exactly when and where to look, the satellite, if within 35 degrees of the zenith and at 200 miles altitude, should first be visible in 7 x 50 binoculars when the sun is two degrees below the horizon. It should be visible to the naked eye if the sun is at least nine degrees below the horizon, so long as the satellite is illuminated by sunlight.

Biology and physics, closely allied in their relation to the astronautical sciences, received the attention of many experts. F. A. Hitchcock, Ohio State University, spoke on the physiology of space flight. He pointed out that man when above some 63,000 feet can be regarded as in space, as far as environmental effects on his bodily organs are concerned. Manned vehicles flying higher than this require an artificial atmosphere to maintain human life in reasonable comfort. Work on such artificial environments is currently being carried out at Ohio State's laboratory of aviation physiology.

Dr. Hitchcock went on to discuss mechanical (liquid oxygen) and biological methods of air conditioning. The latter, by which an equilibrium is established between plant and human organisms, would obviously be preferable for long voyages into space. For this purpose, oxygen-producing carbon-dioxide-absorbing algae might be used. The Ohio State scientist outlined some animal experiments now being made under near-vacuum conditions, and concluded by spelling out the major difficulties confronting human life during flight into space: high acceleration, "zero gravity," aerodynamic heating, vibration, noise, illumination, and visibility. He believes that these are not insurmountable factors.

A number of speakers went into the effects of primary cosmic rays on living organisms. Denmark's C. E. Andersen looked at the dangers from solar corpuscular rays. J. Eugster, of Switzerland, reported that definite effects had been produced by cosmic rays on one-celled bacilli, plant seeds, eggs of crustaceans, and mice. He said that transplants of human skin that had been exposed to such radiation exhibited granulations after some six months, which subsequently changed to pigmented spots.

S. F. Singer, University of Maryland, pointed out that the effects of cosmic rays on both animate and inanimate matter at high altitude can be separated into atomic and nuclear changes. Whereas the former have been intensively examined, the latter have had little analysis. Nuclear disintegration effects are "small but cumulative." Materials containing hydrogen give the most efficient shielding against the heavy primary particles. The question was considered: Would cosmic ray bombardment make the moon's surface radioactive enough to endanger the lives of future exploration teams? Dr. Singer calculated that the most abundant radioactive atomic species on the moon would be tritium, but in such small amounts as to have no biological consequences.

Problems involving missile dynamics, long-range rockets, and optimum launching conditions were discussed in five papers by Italian, British, and Dutch authors. H. E. Newell, Naval Research Laboratory, brought up the role of rockets in the International Geophysical Year. He presented the tentative American plans, which include Aerobee, Booster-Deacon, and Rockoon launchings from Churchill, Canada; New Mexico; the Pacific, off San Diego, Calif.; and the Arctic and Antarctic. More than 150 vehicles are involved, sponsored by three government agencies and one contractor.

The presence of two Russian observers at the IAF congress marked a positive step toward increased world co-operation in astronautics. K. F. Ogorodnikov and L. I. Sedov, of the Soviet Academy of Sciences, said that they were greatly impressed by the aims and activities of the IAF, but that official Russian association with the federation would have to be taken up in Moscow.

Dr. Ogorodnikov is an astronomer at the University of Leningrad, and was a graduate student in the United States during the 1930's. Dr. Sedov, a top aerodynamicist, is now president of Russia's permanent interdepartmental commission on interplanetary communications. The staff of this commission, set up by the academy, includes the astronomers P. P. Parenago, B. V. Kukarkin, and V. A. Ambarzumian.

During the congress of the International Astronautical Federation, president Frederick C. Durant, III, United States, was re-elected, as was vice-president T. Tabanera, of Argentina. General G. A. Crocco, of Italy, was also elected a vice-president, and J. Stemmer, of Switzerland, continues as IAF secretary.

The Chilean Interplanetary Society was admitted to full membership, and encouraging reports on society activities were received from France, Belgium, Mexico, and Peru. Delegates were pleased with the progress of the federation's three-language magazine, *Astronautica Acta*, published by Springer-Verlag in Vienna.

Rome was chosen as the site of the 1956 congress, which will take place September 17-22.

Among the delegates were Eula and Partel from Italy, and Hoie and Christensen from Norway. A. B. C. photos.

Amateur Astronomers

Western Amateurs Yosemite Convention Successful

A DARING EXPERIMENT was an outstanding success. Many enthusiastic amateurs met on Friday through Sunday, August 19-21, in Yosemite National Park, for a convention held far from any city. The 240 official registrations, plus non-registered children, accounted for an attendance of 275. This largest and most successful of Western Amateur Astronomers conventions had three host societies, the Central Valley Astronomers, Stockton Astronomical Society, and Sacramento Valley Astronomical Society, and was under the general chairmanship of Carl W. Anderson. The management of Camp Curry, the convention headquarters, was most helpful, and fine co-operation was given by officers of the National Park Service.

The program of papers was rich fare. Oliver Justin Lee spoke on "Looking Through Great Telescopes," illustrated with motion pictures. Through the generosity of the Astronomical Society of the Pacific we had two Alexander F. Morrison lectures, E. C. Slipher on "Mars in 1954" and Gerald E. Kron on "Photons, Electrons, and Our Universe." Several hundred people attended these three addresses, which were open to the public. For the registrants there were an additional 31 papers by professionals and amateurs. Eight motion pictures were shown. The subjects of instrument making and testing, astronomical observation, and new progress in astronomy were all covered. There was so much material that on two occasions concurrent sessions were needed in order to complete the program in three days.

An exhibition of entries by individuals, observatories, planetariums, and commercial firms was arranged by Victor W. Killick's committee. The exhibit was open to the public and was very well attended. A demonstration of aluminizing by Rolf F. Illsley was one of its features.

The annual banquet Friday evening was followed by the presentation of the G. Bruce Blair award for 1955. This award, in the form of a bronze medal, is presented annually by WAA to a person who has made an outstanding contribution to the advancement of amateur astronomy. Walter H. Haas was the 1955 recipient. His response to the presentation was an address on the early days of the Association of Lunar and Planetary Observers and the *Strolling Astronomer*.

In a literal sense, the highest highlight of the convention was the star party Saturday night. This was held at an elevation of about 7,500 feet near Sentine Dome. The "about" is used advisedly, because there may have been a hundred feet difference between the elevation of the highest and lowest telescopes on the site. Over 50 amateur instruments, ranging in aperture from two to 12.5 inches, were looked through by an estimated 500 persons.

This was the first WAA convention at which a comet could be offered as an attraction. Comet Bakharev-Macfarlane-Krienke (1955f), near Polaris, was visible to the (sharp) unaided eye, and was an interesting object in binoculars and telescopes. The North America nebula, seldom seen by amateurs at sea level, was easily visible in 7 x 50 binoculars and was impressive in rich-field telescopes. All the favorite nebulae, clusters, and double stars shone with unusual brilliance and steadiness without the interference by the murky bottom mile and a half of the earth's atmosphere.

The opinion seemed unanimous that it was a fine idea to hold an astronomical convention in a magnificent natural setting, free from the distractions of cities. It is safe to predict that more than one future western amateurs convention will be held in Yosemite National Park.

HAROLD W. MILNER
350 Tennyson Ave.
Palo Alto, Calif.

J. HUGH PRUETT DIES

After many years devoted to the popularization of astronomy, Dr. J. Hugh Pruett died at his home in Eugene, Ore., on September 25th, at the age of 69. He became interested in astronomy as an Oregon farm boy, and studied physics at the University of Chicago. He was on the faculty of the University of Oregon from 1920 to 1923, later becoming associated with its general extension division.

Dr. Pruett was a recognized authority on meteors, and during his years as regional director for the American Meteor Society was active in discussing fireball reports. He wrote extensively for the public on astronomy, and many readers of this magazine will recall his monthly column, "Terminology Talks," which appeared from 1947 to 1952.

"THE ASTRONOMICAL LEAGUE"

A 16-page booklet on the history, purposes, and activities of the Astronomical League has recently been compiled and edited by Carl P. Richards, of Salem, Ore., and published by the league. The illustrated 8½-by-11-inch brochure is intended to provide background information about the Astronomical League for societies and persons seriously interested in joining, who may procure a copy on request from Joseph A. Anderer, 7929 S. Loomis Blvd., Chicago 20, Ill.

THIS MONTH'S MEETINGS

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. Nov. 4, Dr. I. Epstein, Columbia University, "Magellanic Clouds."

Dallas, Tex.: Texas Astronomical Society, 8 p.m., Lone Star Gas Co. auditorium. Nov. 28, Montgomery B. Groves, "The Use of the T-2 Theodolite."

Geneva, Ill.: Fox Valley Astronomical Society, 8 p.m., City Hall. Nov. 8, V. A. Carpenter, "Magnetism of the Sun and Planets."

Kalamazoo, Mich.: Kalamazoo Amateur Astronomical Association, 8 p.m., Olds Hall, Kalamazoo College. Nov. 12, Dr. Allen V. Buskirk, "Slides from Mount Wilson."

Long Beach, Calif.: Excelsior Telescope Club, 8 p.m., home of Alika Herring, 3273 Liberty Ave., South Gate. Nov. 18, Alika Herring, "How to Figure a Mirror."

Minneapolis, Minn.: Minneapolis Astronomy Club. Nov. 4, field trip, 8 p.m., old University of Minnesota airport.

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. Nov. 2, Joseph M. Chamberlain, American Museum-Hayden Planetarium, "The Ceylon Eclipse Expedition."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. Nov. 5, Dr. A. E. Lilley, Naval Research Laboratory, "The Electromagnetic Spectrum, from Radio Waves to Cosmic Rays."

FLORIDA CONVENTION

Astronomical League 1956 Convention Bulletin No. 1, issued on August 26th, announces the dates of next year's convention as July 2-5, Monday through Thursday, and the place as the McAllister Hotel, Miami, Fla. Field trips are being planned to the U. S. Naval Observatory time station, the University of Miami-Gulfstream AA Observatory, the Junior Museum-Southern Cross AS Observatory, and to Havana's national observatory. Leonard G. Pardue, 641 Falcon Ave., Miami Springs, Fla., is publicity and promotion chairman for the 1956 Astronomical League convention.

NEW YORK AMATEUR CLASSES

Three regular classes, a home study course, and an observing group are among the activities offered to its members this year by the Amateur Astronomers Association. For the purpose of promoting actual observing, the observing group carries on regular scientific programs, and gives instruction to inexperienced members. It meets at various places in suburban New York.

The AAA has its offices at 201 W. 79th St., New York 24, and holds meetings and classes at the American Museum of Natural History. Its president for the current year is W. Wallace Benjamin.

Axial Rotation and Stellar Evolution

Otto Struve, *Leuschner Observatory, University of California*

IN 1929, Sir James H. Jeans wrote in his famous book, *The Universe Around Us*:

"In discussing the way in which nebulae might be born out of chaos, we noticed that the existence of currents in the primordial medium would endow the resulting nebulae with varying amounts of rotation. For the same reason the children of the nebulae, the stars, must also be endowed with rotation at their birth. There is a further reason for such rotation. The general principle of the 'conservation of angular momentum' requires that rotation, like energy, cannot entirely disappear. Its total amount is conserved, so that when a nebula breaks up into stars, the original rotation of the nebula must be conserved in the rotations of the stars. Thus the stars, as soon as they come into being, are endowed with rotations transmitted to them by their parent nebula, in addition to the rotations resulting from the currents set up in the process of condensation."

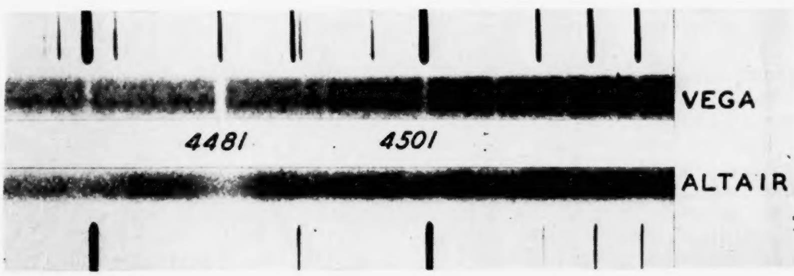


Fig. 1. These short sections of the spectra of Vega and Altair, both A-type stars, illustrate the differing shapes of their spectral lines. Notice how the blue magnesium line (4481 angstroms) appears much broader in Altair, due to the rapid rotation of this star. Yerkes Observatory photograph.

While Jeans was writing these words, several astronomers were at work at Yerkes Observatory studying the absorption lines in stellar spectra. In some stars, such as the sun, Procyon, Sirius, and Tau Scorpii, the lines are narrow and sharp. In other stars of similar temperatures and luminosities, like W Ursae Majoris, Altair, and Eta Ursae Majoris, the same spectral lines appear broad and diffuse (Fig. 1). The Yerkes astronomers concluded that the latter stars rotate rapidly around their axes—with periods of a few hours—while the stars of the first group either do not rotate appreciably or are so oriented that their axes lie close to our line of sight (Fig. 2).

Notice in Fig. 1 that the very sharp and deep line in Vega at wave length 4481 (due to the ion of magnesium) is only a blur in the spectrum of Altair. Measurements of the widths of this line show that the component of the rotation of Vega in the line of sight is zero, while in Altair it is 240 kilometers per second, at the star's equator. Since we do not know whether the axis of Altair is exactly perpendicular to the line of sight, this value is a lower limit to that star's true equatorial velocity of rotation. But let us assume that the axis is actually at right angles to the line of sight.

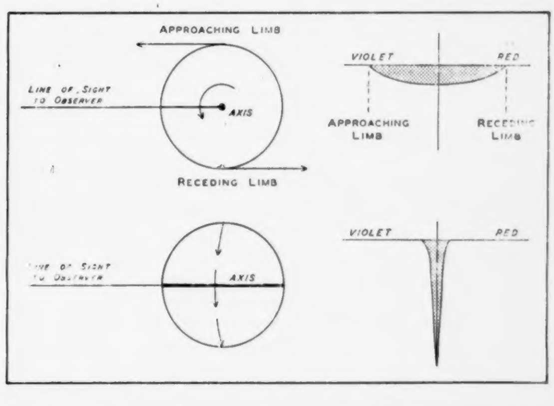
The radius of Altair is about three times the sun's, or 2,100,000 kilometers. Hence the circumference at its equator is 13,209,000 kilometers. A point on Altair's equator, carried by rotation at 240 kilometers per second, would require 15 hours to complete one revolution. This is very much shorter than the rotation period of the sun, which is about one month! If the axis of Altair were inclined at an angle of less than 90 degrees to the line of sight, its rotational period would be even shorter.

In the case of Vega, we do not know whether its rotation is unobservably slow, or whether its pole is turned almost exactly toward us. But as observations accumulated for more and more stars it became clear that some, at least, really have very slow rotations. It seems reasonable to suppose that the axes of the stars are pointed at random, in all directions. Then there should be very few stars with their axes in the line of sight, and a great many with their axes nearly at right angles to it.

I have often demonstrated this to lecture audiences by distributing a supply of matches. I ask each person to hold his match in any orientation that first comes to his mind. I then tell them that I am the observer and their matches represent the orientations of the rotational axes of the stars. Each person estimates the angle between my line of sight and the orientation of his match, and I record on the blackboard the number of matches with angles between 90 and 80 degrees, 80 and 70, and so on, from the line of sight. The result easily demonstrates the great preponderance of the larger angles.

It might be well, however, to warn instructors that this experiment is beset by a systematic error: Even before the audience knows that I shall designate the direction to me as the "line of sight," they seem to be reluctant to point their

Fig. 2. Two rapidly rotating stars are represented. In the upper case, the axis is at right angles to the line of sight, and the spectrum line is widened due to the Doppler effect. In the lower example, no line broadening results because the star's axis points directly at the observer.



matches directly at the speaker. Hence, the preponderance of large angles appears exaggerated in the actual count. Since the mathematical form of the resulting distribution is of course known from statistical theory, a psychologist could, conceivably, use this systematic error to determine the "coefficient of audience-to-lecturer response."

At any rate, it is certain that there are many stars which do not rotate rapidly. If we correct the measured (foreshortened) velocities of rotation for the statistical effect of the random orientation of the axes, we obtain, for stars of different spectral types, the graphs shown in Fig. 3.

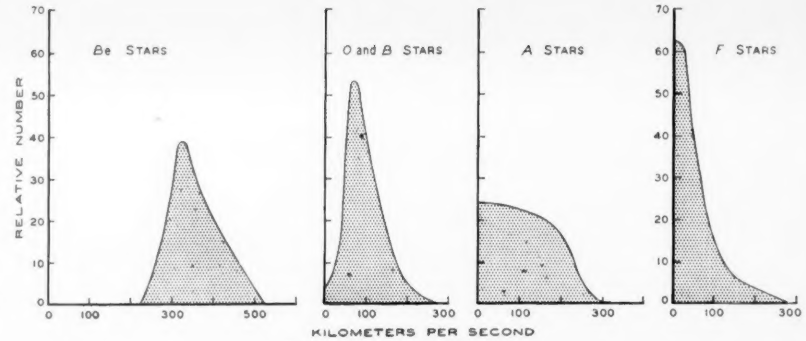


Fig. 3. The relative numbers of rapidly and slowly rotating stars are shown here for different spectral types. The curves, by K. H. Boehm, allow for varying axial orientations of the stars, so the abscissae are equatorial rotational velocities.

We see at once that the *B* stars with emission lines in their spectra (type *Be*) all rotate rapidly—between about 200 and 500 kilometers per second at the equator. Among the *O* and *B* stars, about 10 per cent have no perceptible rotation, while nearly half rotate at 100 kilometers per second, and only relatively few have rotations as large as 175 kilometers per second. For the *A* stars the rotations are somewhat the same, but among the *F* stars about 60 per cent have no observable rotation, and only 10 per cent have rotations of around 125 kilometers per second.

The remarkable decline of the rotational velocities as we pass from the early spectral types to the later ones was already known 30 years ago, from the work of Elvey and myself. It poses an interesting evolutionary problem, when we consider that presumably all stars which are now located on the main sequence of the H-R diagram have been formed by the gravitational contraction of globules of interstellar matter. These are nearly spherical dark cloudlets, discovered by B. J. Bok at Harvard in such gaseous nebulosities as M8 (Fig. 4). Globules have diameters of the order of 10,000 astronomical units. Their masses are not known, but they presumably range between one and 50 solar masses, similar to the masses of the stars. They are sufficiently compact to resist disruption by tidal effects of the Milky Way as a whole, and of neighboring stars. They contract fairly rapidly: G. P. Kuiper has computed that a globule of solar mass and initial radius of 10,000 astronomical units will become a luminous protostar in about 100,000 years. From then on, the evolution gradually slows down.

L. G. Henyey, R. LeLevier, and R. D. Levee have recently shown that a protostar of solar mass and surface temperature 2,500° needs about 30 million years to reach the present position of the sun in the H-R diagram, with surface temperature 6,000°. Even so, this evolutionary stage of contraction, with energy generation from nuclear reactions only beginning to play a role toward the end of the stage, is short compared to the 100 billion years that the sun will presumably have needed for its later development. No wonder that among the stars observed at random we find few, if any, that are now in the early, contracting stage of evolution.

Nevertheless, if our ideas are correct, we should expect all individual stars that are now located on the main sequence to retain the rotation (angular momentum) of the original globules. There is no reason to suppose that globules of small mass had, to begin with, less than their normal supply of angular momentum per unit of mass. Therefore, we should have predicted that the frequency distributions in Fig. 3 should have been the same for stars of all spectral types.

The slow rotation of the later *F*-type stars, and of classes *G, K,* and *M,* must be the result of an evolutionary phenomenon not considered in the theory of contracting globules. I have previously suggested that this phenomenon is the formation of systems of planets. If, as seems likely, many main-sequence stars have developed not as single bodies but as planetary systems, a large part of the original angular momentum of the globule would now reside in the orbital motions of the planets.

The sun, for example, if it could absorb within its body all of its attendant planets, would spin around its axis at some 60 kilometers per second—becoming a fairly rapidly rotating single star. In reality, its equatorial rotational velocity is only two kilometers per second; and the remainder of the angular momentum is shared among the planets. To me, this is a very strong argument in favor of the hypothesis advanced by Kuiper and others, on different grounds, that planetary systems are the rule and not the exception among stars of spectral classes *F, G, K,* and *M.*

But what of the stars of early spectral class? Presumably they have developed from the contraction of the more massive globules, as single, double, or multiple stars (without planets). They possess, even now, the large angular momenta that were originally present in the globules. What will happen to the rotation of these stars as they subsequently evolve by the conversion of their hydrogen into helium?

In the first place, the contracting stage of evolution of these massive globules and protostars is even shorter than for the globules of solar mass. According to Henyey and his collaborators, Sirius with a mass of 2.3 suns required only three million years to change from a protostar of temperature 4,000° absolute to its present state with a temperature of 10,000°. An even more massive star, like Tau Scorpii, may have needed only a few hundred thousand years. These intervals are so short that our chances of actually observing a protostar of large mass in the contracting stage are quite poor.

But we do observe many early-type stars which are subgiants, a little more luminous than main-sequence stars of the same spectral types. These are believed to have evolved appreciably from the main-sequence stage, because they have

Fig. 4. The arrows point out dark globules in this Lick Observatory photograph of the diffuse nebula, M8, in Sagittarius.

had enough time to use up a large fraction of their original supply of hydrogen by converting it into helium. We have previously seen (*Sky and Telescope*, January, 1953, page 63) that these stars of advanced evolutionary age occur in certain galactic clusters, such as the Pleiades and the Hyades, and also among the single or binary subgiants.

The evolutionary tracks of stars, in this second stage of their development, are known from the theoretical work of A. R. Sandage and M. Schwarzschild. They are illustrated in Fig. 5. Let us take a specific example. The star Xi Geminorum is now a subgiant of spectral class *F*5; its visual absolute magnitude is +1.9, and its observed rotational velocity is, according to J. B. Oke and J. L. Greenstein, 73 kilometers per second. Its present spectral type implies a surface temperature of about 6,500°. If we locate this star in Fig. 5 by its temperature and its absolute magnitude (the visual magnitude of this star is almost the same as its bolometric magnitude), we find it in the position marked X.

We infer that the mass is about 1.5 suns, and that, to begin with, Xi Geminorum had an absolute magnitude of about +3.3 and a temperature of about 7,500°. It is now about four times more luminous and 1,000° cooler than when it was located on the main sequence. Now, as the temperature decreases from 7,500° to 6,500°, the light emitted by every square centimeter is less by a factor of $(6{,}500/7{,}500)^4 = 0.56$. But the total luminosity is now *greater* than before by a factor of four. Hence, its surface area has increased about seven times and its radius by a factor of $2\frac{1}{2}$, which is roughly in agreement with a more exact calculation by Oke and Greenstein giving nearly 2.

The present rotational velocity of 73 kilometers per second is statistically improbable for a main-sequence star of class *F*5. But if Xi Geminorum was originally a main-sequence star having a temperature of 7,500° (corresponding to spectral class *A*8), its rotational velocity would have been 2 × 73 = 146 kilometers per second—because of its smaller original size—and this larger velocity of rotation is not at all unusual among main-sequence stars of class *A*8. Thus, Xi Geminorum seems to fit our ideas concerning the conservation of angular momentum during the evolution of a star without planets.

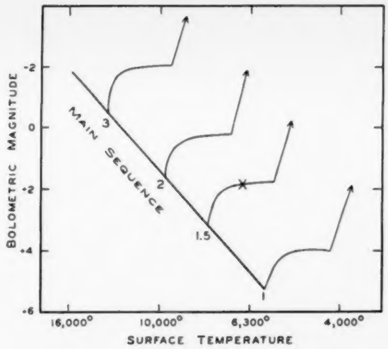


Fig. 5. The evolution of subgiant stars, according to the Sandage-Schwarzschild theory, is plotted on this luminosity-temperature diagram. Xi Geminorum, once on the main sequence, has followed the curved path to its present state, marked by a cross.

In recent years a vast amount of new information on stellar rotation has become available through the work of S. S. Huang, G. H. Herbig, and J. F. Spalding, and particularly A. Slettebak. The latter has systematically observed all accessible stars brighter than the 5th magnitude, of spectral types *B*2 to *G*0. The resulting distributions of the observed foreshortened axial rotations of those stars that lie on the main sequence are shown in the upper parts of Figs. 6 and 7. These patterns are substantially similar to those derived from previous measurements.

But Slettebak has also measured the rotational velocities of many subgiant stars. For these Sandage has computed the ratio of the present radius to the original one, using substantially the same procedure we employed for Xi Geminorum. This has enabled him to compute for each star the original, faster axial rotation—referred to the time when each star was a main-sequence object. The resulting values, using certain assumptions concerning the arrangement of mass within the evolving star, give a set of computed distributions, in the lower parts of Figs. 6 and 7.

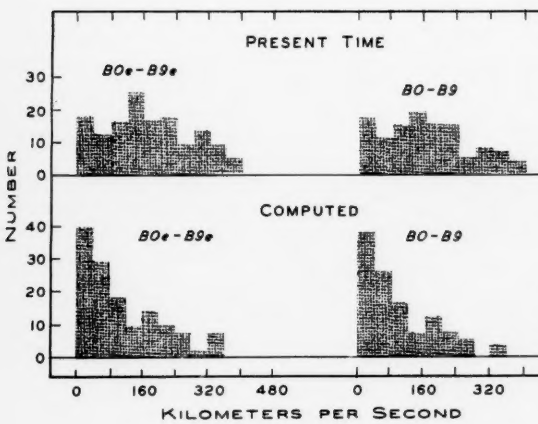
The computed frequencies should resemble those observed at present, if recently formed stars on the main sequence rotate like those that were on this sequence some 10 or 100 million years ago. Actually, the computed patterns closely resemble the present ones for spectral classes *A*0 to *G*0 (Fig. 7). But among the *B*-type stars (Fig. 6) the present distribution contains many more rapidly-rotating stars than the computed distribution.

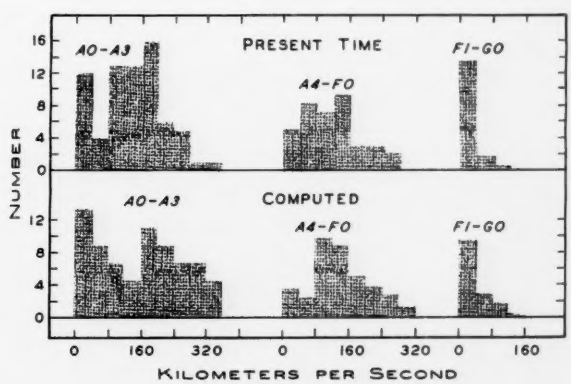
Sandage remarks that this discrepancy may mean that the *B* stars have not conserved their original mass during their evolution. Actually, the nuclear conversion of hydrogen into helium reduces the mass of a star, at most, by only 0.7 per

(*Continued on page 50*)

Globular Cluster Orbits

In connection with my June article on the galactic orbits of globular clusters, Prof. Lubos Perek, of the Astronomical Institute of the University in Brno, Czechoslovakia, has called my attention to an article entitled, "A Note on the Galactic Orbits of Globular Clusters," which he published in issue No. 12, Vol. 1, of the *Contributions* of his institute. He has, independently of von Hoerner, reached the conclusion that globular clusters move predominantly in highly eccentric orbits around the nucleus of the Milky Way. O. S.





Figs. 6 and 7. These diagrams show (above) the presently observed distributions of rotational velocity for different spectral types (Be stars—those with bright spectral lines—are separated from ordinary, dark-line, B stars). The lower diagrams give the corresponding distribution of rotations, computed by A. Sandage for the remote past, when stars that are now subgiants were presumably on the main sequence.

☆ ☆ SKY AND TEACHER ☆ ☆

Sponsored by the
Teachers' Committee of the American Astronomical Society

GETTING TO BE AN ASTRONOMER

IF YOU ARE enthusiastic about the stars, the $64,000 question may one day arise: Shall I make the stars my lifelong job? Shall I try to become a professional astronomer? Most probably, your interest in astronomy was evoked some years ago, and as this interest deepens and matures, you are going to ask what the business of being an astronomer is like and how to set about becoming one. You may want to decide now, although for some young men and women the yes-or-no decision is made during the college years, or even after them.

First, think long and hard about yourself to see if you have most of the right ingredients. The recipe calls for three things of fundamental importance. First, you must love the subject—nearly all astronomers are happy at their work. As in any job, of course, there are some routine or tiresome tasks. But it is this love of the subject that provides the will to hurdle the unglamorous parts. Also, real devotion is essential because it will override the obvious disadvantage of somewhat low income.

Second, and equally important, is intelligence. You don't have to be in the top one per cent of your class as far as grades go, but you should be close to it. Clearly, brain power is needed to complete the educational requirements of an astronomer, and it is essential if you are ultimately to contribute to astronomical learning and teaching. Your ability in physics and mathematics ought to be especially high, because their subject matter and techniques are used extensively in astronomical work.

Third, you must have the urge to know, to use your intelligence and not let it sleep. This means not simply looking up the answer in an encyclopedia, but rather figuring it out for yourself. Astronomy is special among the physical sciences because its facts are rarely sought for practical use or financial gain, but rather because of a vigorous curiosity.

Given these essentials, what education must you have to become an astronomer? At present, and in the foreseeable future, most job openings in professional astronomy at colleges and observatories are for persons with, or soon to obtain, their Ph.D. degrees. Ordinarily, attainment of this doctorate takes about eight years of college life.

Your program begins with four years of undergraduate work. Along with many required and elective courses in other fields, you will concentrate, chiefly in your junior and senior years, in scientific subjects. If you happen to be enrolled at one of the 35 colleges offering a major in astronomy, you will follow the courses described here in September (page 459). At other institutions, you will probably major in physics or mathematics and elect such courses in astronomy as may be offered. Both of these types of curriculum are entirely acceptable for admission to one of the graduate schools of astronomy.

After earning the bachelor's degree, and possibly spending some time in the armed services, you will begin graduate work. Few universities in the United States offer graduate programs in astronomy, which is not surprising when we realize that there are only a few hundred astronomers in the country and that only 10 to 15 astronomy doctorates are awarded each year. The larger programs are at California, Chicago (Yerkes), Harvard-Radcliffe, and Michigan. Other institutions that have granted one or more Ph.D. degrees in astronomy over the past 15 years are Caltech, Columbia, Georgetown, Illinois, Iowa, Northwestern, Pennsylvania, Princeton, Virginia, Wisconsin, and Yale.

In graduate school during the first two or three years, a variety of advanced courses in astronomy are taken, with some advanced physics and mathematics. Also during this time, you prepare to take reading tests in two modern foreign languages (usually selected from French, German, and Russian), to insure that you can keep up with current foreign research. You will be learning, as an extracurricular activity on clear nights, how to handle telescopes and accessory equipment. You will probably want to earn your own living—at least partially—during these years, and it is usually possible to obtain a teaching assistantship or research assistantship in astronomy. The average stipend for half-time work is close to $1,500 for the academic year. By such an arrangement you gain valuable teaching or research experience.

At some stage of graduate work, you will be required to take preliminary examinations. These long and exhaustive tests cover the entire field of astronomy at a distinctly advanced level. When you have successfully completed them, you have presumably achieved a good understanding of astronomy as a whole. You are then ready for specialization. During this time, you will probably have become excited about a research problem—an interpretation of the spectra of novae, or the distribution of radio stars, or the photometry of comets. If the problem has sufficient scope, it may form the subject of your Ph.D. thesis, which is intended to show your capacity to carry through an original research project, with the help and constructive criticism of your advisers. Finally, when this is completed, it is customary for the staff of your department to examine you orally on all fields related to your thesis. If this is successful, you are at last awarded the degree.

You are now on your own. Are there jobs available to you? At present, the demand for astronomers exceeds the supply, and this situation will probably continue if the annual number of astronomy doctoral degrees does not rise markedly. First, there is an increasing demand for teachers in all subjects, including astronomy, because college enrollments are rising. Second, research in pure science is being increasingly fostered financially by corporations and by the government.

The kinds of jobs available to astronomers, both men and women, are twofold: university or college work and observatory work. The astronomer at a university ordinarily teaches several courses in astronomy (and sometimes physics or mathematics). He devotes the time remaining after lecturing and administrative duties to original research of his own choosing. The relative time for teaching and research varies, depending on the institution, the department, and the individual. The majority of astronomers fall in this university category.

Aside from administrative work, an observatory astronomer can devote all his time to research, on projects of general interest to his observatory staff as well as on those of his own choice. But the two kinds of position are not mutually exclusive. Often the university astronomer will spend summers doing research at an observatory. Alternatively, the observatory astronomer may occasionally accept a lectureship at one of the colleges. Whatever the ratio of teaching to research activity, nearly every astronomer participates to some extent in both.

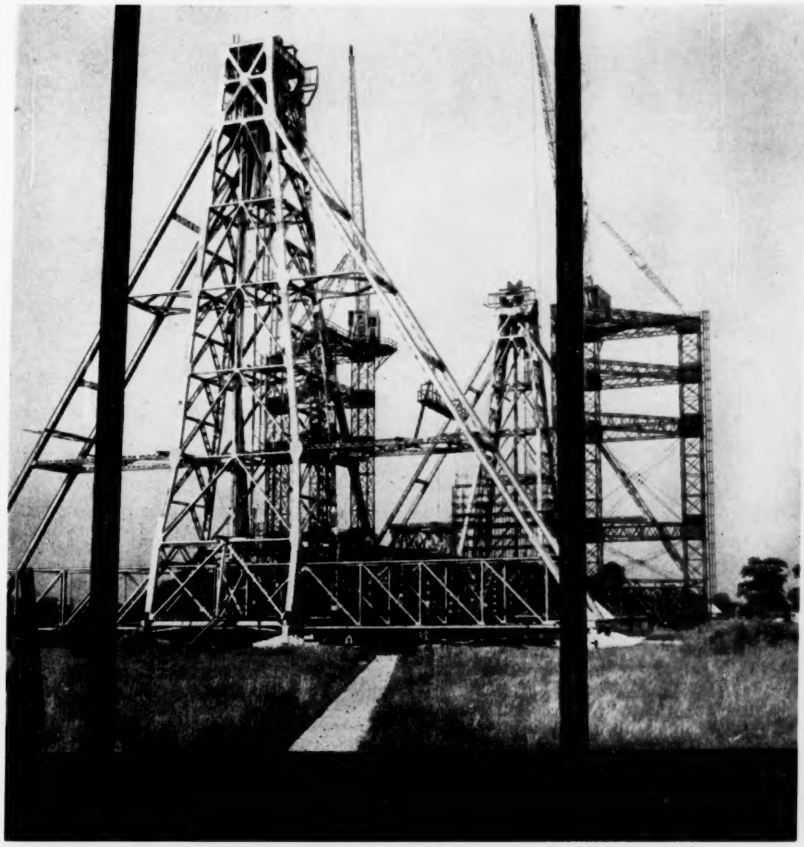
The starting salary of an astronomer who has just received his Ph.D. degree depends on many things: the present cost of living, the law of supply and demand, the record of the applicant, and so on. A typical figure for the nine-month academic year is somewhere near $4,000. Although this is considerably lower than would be offered by industry for the same level of intellectual attainment, if you are the kind of person who can be happy only as an astronomer, this disparity is overbalanced by love of your work.

Advance in salary and rank follow, as in other work, with increase in experience and responsibilities, so long as you do not fall mentally asleep on the job. Even with a family and a home, you will never lack for a loaf of bread. Neither are you ever likely to join a swank country club—and you perhaps won't want to. And at 65 or so, when you may have to retire formally, you will probably still be found putting in time at an observatory and contributing to astronomical learning.

STANLEY P. WYATT, JR.
University of Illinois Observatory

Jodrell Bank Symposium on Radio Astronomy

Bart J. Bok
Harvard College Observatory



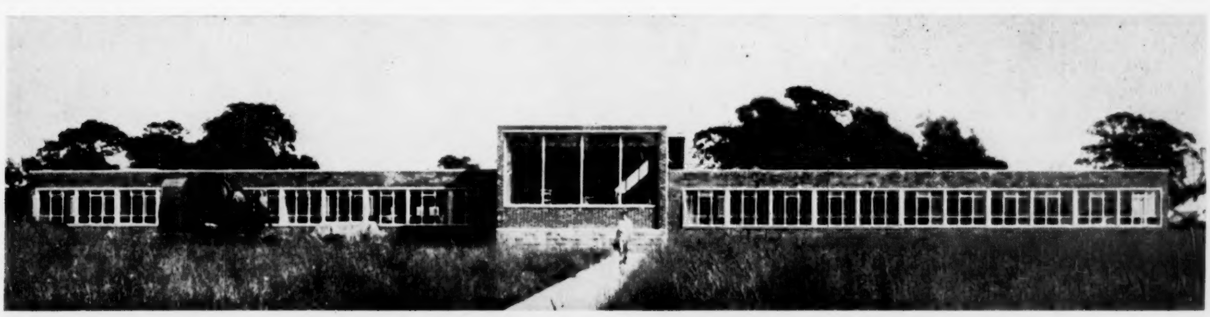
Late in August, this picture was taken of the 250-foot radio telescope under construction at Jodrell Bank. It is seen through the control room window pictured below. At the left is one of the two main pedestals of the altazimuth mounting—the other is in the distance. The 250-foot paraboloidal antenna will be suspended between them. There are two tall erecting cranes on triangular structures (see page 26), one partly obscured by a vertical rib of the window. To the left of the footpath is a supporting truck, shown in close-up on page 27.

FOR THREE DAYS starting August 25th, 125 radio astronomers met in the shadow of the new 250-foot steerable radio telescope of the Jodrell Bank Experimental Station of the University of Manchester, in England. This symposium on radio astronomy was held under the auspices of the International Astronomical Union just prior to the Dublin meetings, and was attended by astronomers, physicists, and radio engineers from 19 nations.

The principal organizers of the symposium were J. P. Hagen, U.S.A.; M. Laffineur, France; our host, A. C. B. Lovell; J. L. Pawsey, Australia; and H. C. van de Hulst, Holland. It was the most concentrated three-day symposium I have ever attended, with some 95 papers that we could have spent a full week discussing and analyzing.

A feature of the program was a tour of all the observing equipment and research buildings at Jodrell Bank. Many unique developments and new instruments have come into existence since Dr. Lovell's article in this magazine in February and March, 1953. The tour chart, on page 23, gives a good idea of the diversity of present Manchester activities.

One cannot visit Jodrell Bank without being at all times aware of the presence of the giant radio telescope, which is approaching completion. The meetings were held in the new administration building, and our eyes occasionally wandered to look through one of the large windows of the lecture room at the giant being erected. H. C. Husband, designer of the 250-foot telescope, took us around to see the state of the work. At the time of the symposium, the drafting work had been completed, and most of the elements of the instrument had been constructed and were being assembled at the site. The two big towers and the central pivot are up, as the pictures show, but the big "dish" itself is not in place. The control



Large windows, in the control room of the new administration building, dominate the side that faces toward the 250-foot radio telescope. The lecture hall is at the extreme left. Photograph by the author.

room is in the center of the administration building, and its electronic equipment and control panels are a marvel to behold.

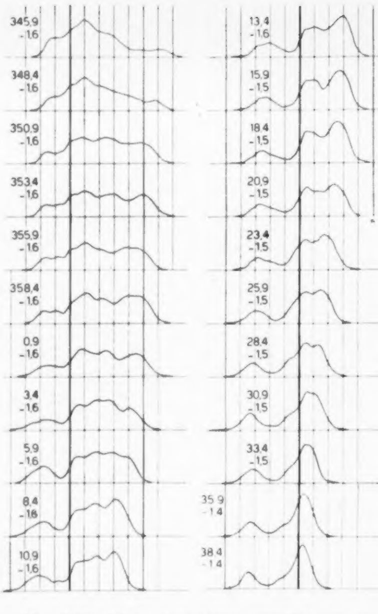
Hydrogen in the Milky Way

The biggest scientific news of the symposium was the announcement by the Soviet delegation of the discovery by G. G. Getmanzev, K. S. Stankevitch, and V. S. Troitsky, of the radio spectrum line at a wave length of 91.6 centimeters (frequency 327 megacycles per second) due to interstellar deuterium. This is the isotope known as heavy hydrogen, since it has twice the mass of the ordinary hydrogen atom.

We have known for many years that interstellar hydrogen should have a deuterium component, but it was expected on mostly theoretical evidence that there would be only one deuterium atom for every 6,000 normal hydrogen atoms and that the radiation at 91.6 centimeters would therefore be very difficult to detect. The Russian observers have, however, found the line as a small absorption dip in strong radiation from the direction of the galactic center. This radiation corresponds to a source temperature of 300° absolute, and the dip has a depth of 2.5°, which suggests that, for the galactic center direction at least, the deuterium-hydrogen abundance ratio may be as high as 1 to 400. The Russian observation obviously requires checking and confirmation, but there is no doubt of its great importance, possibly ranking with the discovery in 1951 of the 21-cm. line by H. I. Ewen and E. M. Purcell.

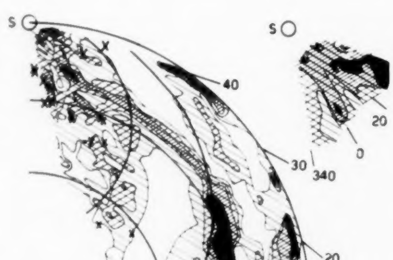
As readers of *Sky and Telescope* well know (for instance, see page 408, October, 1954), the study of 21-cm. radiation from various directions gives important clues to the spiral structure of the Milky Way; it is also a valuable tool for the study of interstellar neutral hydrogen that supplements information about interstellar ionized hydrogen obtained from optical studies of gaseous nebulae and interstellar gas.

At Jodrell Bank, the first half of the 21-cm. session dealt with galactic structure, and here the Leiden group deserves the blue ribbon. Under the inspiring leadership of J. H. Oort and van de Hulst, significant advances have been made in two important areas of investigation. G. Westerhout has obtained 21-cm. profiles at positions 2½ degrees apart along the Milky Way from Cygnus to beyond Sirius and from 10 degrees south to 10 degrees north of the equator of the galaxy. He demonstrated an impressive plastic three-dimensional model of this arc of the Milky Way, which shows nicely the separate spiral arms and how they branch off in spots, very much as do the spiral arms in galaxies outside our own. All three arms beyond the sun are not precisely in the same plane, but otherwise they conform to the generally accepted picture of spiral structure.



M. Schmidt's intensity profiles were made at 2½-degree intervals along the Milky Way central plane. The horizontal scale (divided by the vertical lines into units of 100 kilometers per second) represents the motion of the neutral hydrogen gas with respect to the observer. This, in turn, indicates the distance and position of the gas in our rotating galaxy.

To supplement Westerhout's study of the spiral structure at greater distances from the galactic center than our sun,



This map of neutral hydrogen distribution in the galactic plane is deduced from the line profiles above. S is the sun, and C the galactic center. Both diagrams are from Leiden Observatory.

M. Schmidt has observed the inner parts of the system. Here the interpretation of the 21-cm. profiles is not as simple as for the outer regions, since radiation at any one frequency may be emitted from two different points along a particular line of sight. But through a process of successive approximations, Schmidt has begun to disentangle the complex profiles and a first rough picture begins to emerge, with two notable features:

First, the spiral structure appears to continue inward from the sun to within 10,000 light-years of the center (the sun is presumably at 26,000 light-years). Second, there is much neutral hydrogen in the innermost parts of the galaxy. The great range in distance over which the Milky Way spiral structure is spread (from 10,000 to well over 40,000 light-years from the center) makes one wonder if we really are in an Sb-type galaxy or, perhaps, in a somewhat more advanced type!

Research in spiral structure is being pressed at several observatories. For the Northern Hemisphere, Howard E. Tatel, of the Carnegie Institution of Washington, and Thomas A. Matthews, of Harvard, presented papers with detailed data on spiral structure for lines of positions closely spaced at certain points on the galactic circle. For the Southern Hemisphere, Martha Stahr Carpenter, of Cornell University, just returned from a year at Sydney, reported steady progress there. But we are still quite a way from the final picture for the southern part of the Milky Way. However, Frank J. Kerr and his associates are assembling very useful information and, with the completion of their new equipment in sight, we may soon expect to see the south catch up with the north.

Among five Harvard papers on 21-cm. research, my own gave a general survey of our program and of equipment now in operation and under construction. We hope to have our new 60-foot equatorially mounted paraboloid ready early in 1956. The electronic equipment Ewen is building for this antenna will receive 20 channels or wave-length regions simultaneously; there will be direct typewriter recording of the results. Papers by T. K. Menon and R. S. Lawrence illustrated the general plan of the Harvard work: to correlate radio and optical studies of the details of galactic structure.

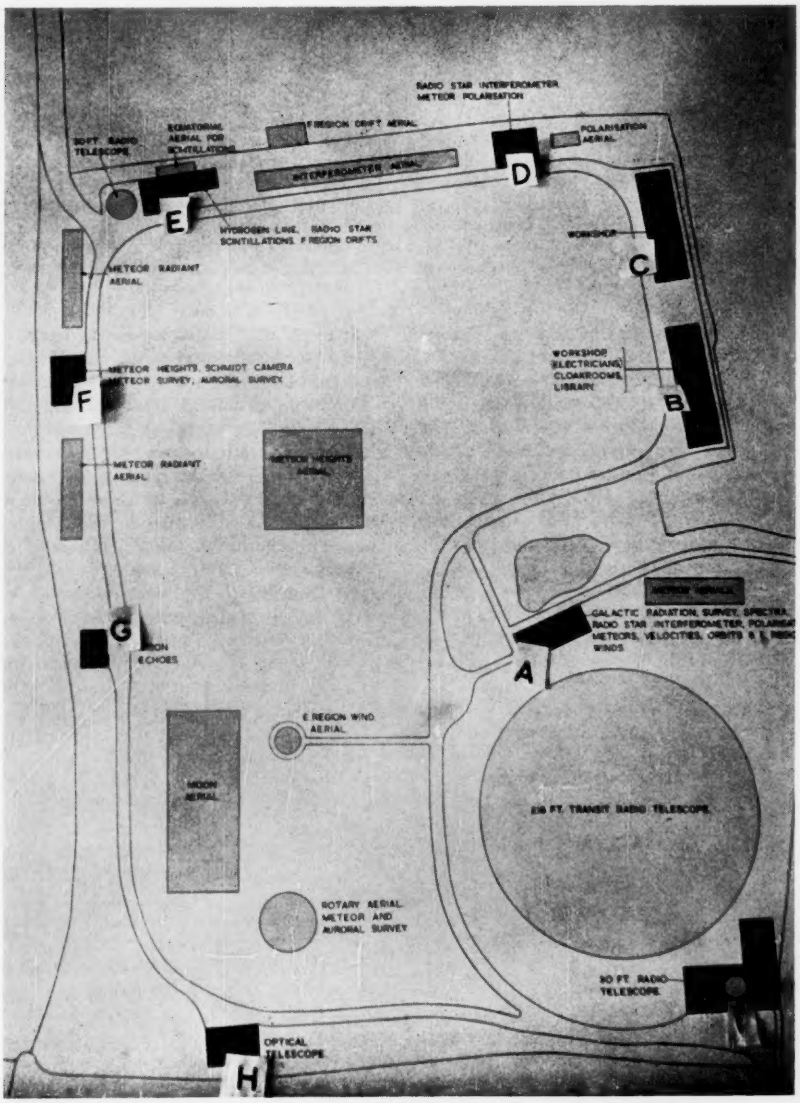
Menon is studying the whole section of Orion that contains the Great Nebula, the Horsehead nebula, the great arc of nebulosity discovered by E. E. Barnard more than 50 years ago, and the aggregates of *O* and *B* stars. Menon's principal result is that all the above-named objects are embedded in a huge bowl of neutral hydrogen jelly—with a total estimated mass of 60,000 solar masses. The 21-cm. profiles suggest that this neutral hydrogen complex is expanding at about 10 kilometers per second and, most interestingly, that the center of the expansion is not the

Great Nebula but rather in a position near the center of the Orion aggregate of O and B stars and of Barnard's great arc.

This work illustrates how 21-cm. research supplements optical studies. In the past we had information only on the distribution of ionized hydrogen and other less common gases, but now we are adding radio data on the most common interstellar gaseous component, neutral hydrogen.

Lawrence described his attempt to correlate 21-cm. data, for the regions immediately surrounding certain stars, with interstellar absorption lines observed optically in high-dispersion spectra obtained by G. Muench at Mount Wilson and Palomar. Lawrence finds, in at least one case of a star far from the galactic plane, a clear-cut correspondence with an isolated neutral hydrogen cloud showing the same radial velocity as that measured from the interstellar lines of calcium and sodium. In this kind of work, however, with present-day equipment most radio astronomers deal with neutral hydrogen clouds $1\frac{1}{2}$ degrees across, whereas the optical astronomer uses probes in an extremely narrow beam. As larger paraboloidal antennas are built, we shall be able to make radio studies of smaller and smaller clouds, and may be able to detect the individual component clouds of the interstellar gas.

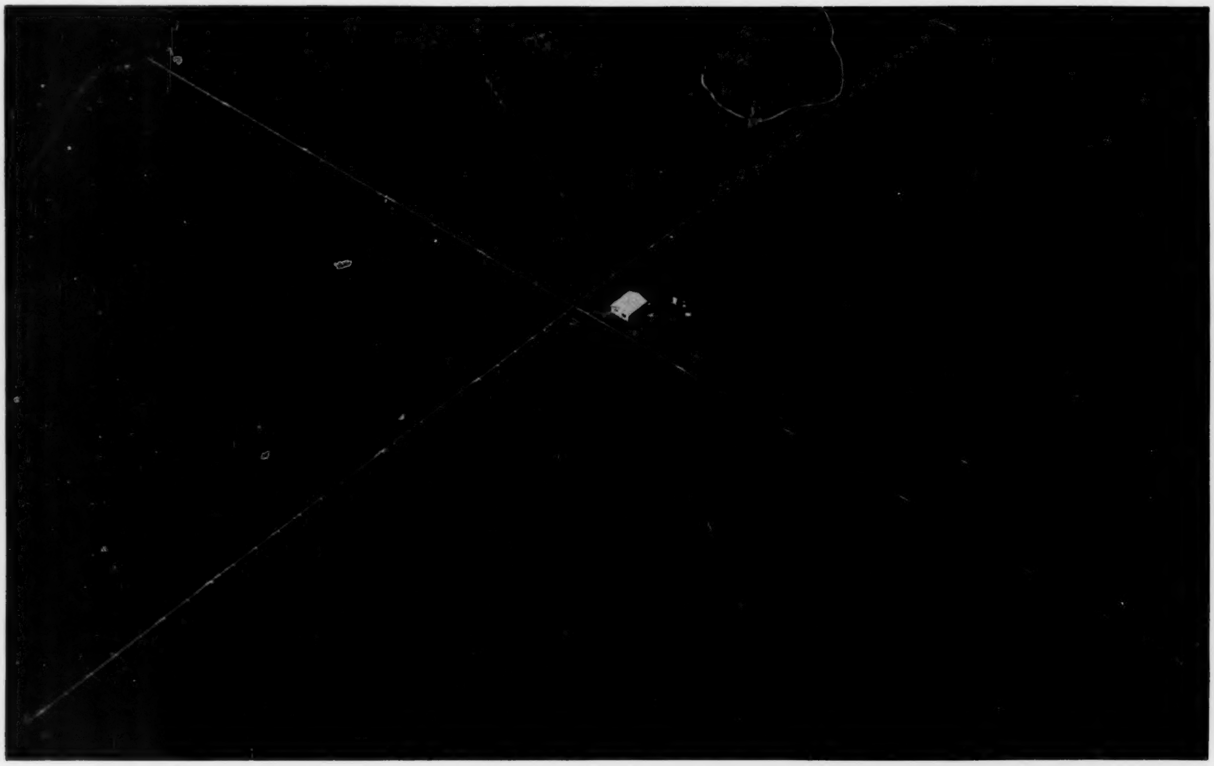
With the aid of the tour chart, Dr. Lovell described Jodrell Bank activities.



The tour chart of Jodrell Bank indicates the diversification of radio astronomy programs at the experimental station. The new administration building and the 250-foot telescope are outside the area covered by this map, well above and to the left.

The final hour of the 21-cm. session was devoted to absorption features in such discrete radio sources as Cygnus A, Cassiopeia A, Taurus A, and the strong source in the direction of the galactic center. Here there was plenty of controversy, centered upon two principal problems. The first is the distance of the Cassiopeia A source, which has been identified with galactic nebulosity. Radio data strongly support a distance of the order of 10,000 light-years (papers by R. D. Davies, A. E. Lilley, and Hagen), but Walter Baade and Rudolf Minkowski, of Mount Wilson and Palomar Observatories, have new optical evidence suggesting a distance of not more than 1,500 light-years. No decision!

The second problem is the distance of the strong source toward the galactic center. E. F. McClain, Naval Research Laboratory, has made the most accurate and complete study of the profiles for positions on and near the source. From the absorption curve he places the source 10,000 light-years away, much closer to us than the galactic center. He is supported by R. D. Davies, of Jodrell Bank, who uses the measured total amount of absorp-



The original Mills cross radio antenna, invented by B. Y. Mills, is at St. Marys, near Sydney, Australia. Each arm is 500 yards long and contains 500 half-wave dipoles above a sheet of wire-mesh reflector, as shown in the photograph opposite. The combined beam is 0.8 degree wide and can be swung in the meridian plane 45 degrees either side of the zenith. The wave length is 3.5 meters. The cross has a high angular resolution, about that of a paraboloid of equal diameter. The photographs and information were transmitted by Frank J. Kerr, Division of Radiophysics, CSIRO, Australia.

tion to find the distance. However, F. G. Smith, of the Cavendish Laboratory, Cambridge, places the source still right at the center of our galaxy. His interferometric studies at various frequencies indicate that the source lies very close to the precise direction of the galactic center. He also finds that the source's radiation at the longer wave lengths is too great to consider it as originating in a cloud of ionized hydrogen by the usual thermal process, as other tentative identifications of this source seem to imply.

Discrete Radio Sources

Most of the second day of the symposium was devoted to discrete radio sources (formerly called radio stars, often rather loosely). Whereas 21-cm. radiation is a well-understood physical process, we now come face to face with spectacular but unexplained phenomena of unknown origin. There is ample room for controversy of the kind that occurred aplenty on the second day.

In his introductory lecture, Minkowski stressed the need for very precise radio positions to facilitate identifications with optical objects. Two important new catalogues of discrete radio sources are soon to be published. The first is the Cambridge catalogue by M. Ryle and his associates, which contains positions of 1,936 objects found with the giant interferometer array of the Cavendish Laboratory. The second catalogue, by B. Y. Mills and his co-workers at Sydney, has over 1,000 entries and is still growing in size. The Australian observations are made with a Mills cross of matched receiving arrays that give essentially the resolving power of a large paraboloid of comparable linear dimensions; the Cambridge technique differs basically from that used by the Australian observers. As yet no source-by-source comparison has been made between the two catalogues, but the statistics of numbers of sources according to their radio brightnesses are quite different, with the Cambridge data yielding a very much faster rate of increase than do the Sydney results in the numbers of sources with decreasing apparent radio brightness.

Attempts at identification of the strongest radio objects newly observed by Ryle and his group have not been very successful. Both D. W. Dewhirst, of the Cambridge Observatory, and Minkowski at Mt. Palomar reported essentially negative results. The Australian observers were somewhat luckier, with Pawsey reporting 10 normal galaxies, one pair of apparently colliding galaxies, one additional supernova, and several emission nebulae (including the famous Eta Carinae nebula), as having marked radio sources at their optical positions. These southern results are not surprising, for the northern sky had already been pretty well "milked dry" as far as the more obvious identifications are concerned. Attempts to find radio evidence for globular clusters were not successful, and Dewhirst and Pawsey found no detectable radio radiation from normal novae.

There was considerable discussion—especially later in Dublin—of the possible cosmological consequences of the surprisingly large numbers of faint sources in the Cavendish statistics, but in view of the rather different Australian results and the lack of positive identifications with optical objects, the time does not seem ripe for such speculations. We are still very far from a real understanding of the nature of the faint sources. Ryle considers that they are mostly galaxies (possibly like the faint colliding pair 200 million light-years from the sun that is responsible for the very strong Cygnus A source), and practically all of them beyond the reach of even the 200-inch telescope. On the other hand, A. Unsold suggested that most of the radio radiation comes from highly active cool stars of low absolute magnitude—of the nature of red flare stars—and that these same stars may also produce cosmic rays. At present

there is no sure way of deciding between these two very different hypotheses.

There was mostly agreement, however, in one area of research. Various efforts are being made to establish for the better-known radio sources the dependence of the radio brightness upon wave length; in other words we are beginning to gather information about the spectral energy distributions of the radio sources in the radio range. At the Dublin meeting, Charles Seeger, of Leiden Observatory, brought together in one diagram the available—mostly unpublished—data for the Cassiopeia A source.

At the short-wave end, in the 3-cm. range, two observations are available, one by Haddock and McCullough of the Naval Research Laboratory, the other by two Russian observers, Razin and Plechkov, and these give an intensity of 4×10^{-24} watts per square meter per cycle per second (at 9,500 megacycles per second). For longer wave lengths, the curve of Cassiopeia A radiation appears to rise rather steadily to a frequency of about 500 megacycles per second, and then it apparently flattens out at an intensity level of 40 to 60 x 10^{-24} of these same units. It stays that way to about 200 megacycles per second (wave lengths 60 to 150 centimeters for the flat portion). After that the curve rises steeply to reach a high somewhere between 500 and 1,000 units, near a frequency of 23 megacycles (wave length about 12 meters), dipping again—according to observations at Jodrell Bank and at the Carnegie Institution of Washington—and maybe becoming as low as 100 units at 15 megacycles or about 20 meters.

One of the best moments at Jodrell Bank came after John P. Hagen, Naval Research Laboratory, had finished a blackboard sketch of his results and those of various British, Dutch, and American observers, and then S. B. Pikelner from the Crimean Observatory stepped forward to enter two Russian observations in the diagram—there was perfect agreement at the wave lengths in question.

What are the results? The spectra of the brighter sources are all rather similar to that of Cassiopeia A above, with high intensity for the long waves (except for the Crab nebula, which flattens out at longer wave lengths). But this is not the case for radio radiation from the known emission nebulae: the Orion nebula, the Lagoon and Trifid nebulae, and others. These objects are detectable only at high frequencies; the absence of perceptible long-wave radiation shows that the source is probably purely thermal, that is, the radio radiation originates from encounters between free electrons and protons. Temperatures of the order of 10,000° absolute suffice in most cases to explain the observed radio intensities for these nebulae. Thus, we appear to be dealing with at least two varieties of radio sources.

Temperatures of millions of degrees would be required to produce the observed high intensities in the meter wave length range for the bright sources such as Cassiopeia A, Cygnus A, and the like. At Jodrell Bank a number of fruitful suggestions were made to explain the origin of these strong radiations. Among the leaders in interpretation are two Soviet radio astronomers, I. S. Shklovsky and V. L. Ginsburg. They have suggested that the radiation comes from relativistic (very fast-moving) electrons, the motions of which are determined by interstellar magnetic fields. This type of mechanism was considered carefully in a survey talk by J. L. Greenstein, California Institute of Technology. The magnetic interpretation has received a terrific boost quite recently through the results of optical research on the Crab nebula, which is known to be the remnant of a supernova outburst in the year 1054. A few years ago Vashakidse and Dombrovsky in the USSR discovered strong polarization, averaging about 12 per cent, in the light of the Crab nebula. Crimean Observatory astronomers and Oort and Walraven at Leiden have independently confirmed and extended this work—the polarization may be close to 100 per cent for a few condensations in the nebula. The relativistic electron mechanism appears most suitable to explain the observed high polarization. Oort estimates the required magnetic field to be of the order of 1/1,000 gauss, but Shklovsky favors a field only 1/10 as strong.

In his talk, Greenstein discussed the processes that might take place in collisions between gas clouds—the type of collision that appears to be responsible for the radio radiation from the pair of colliding galaxies, Cygnus A. There is a large store of energy available in any collision between two galaxies. The problem is to convert this kinetic energy of motion into radio energy of the observed wave lengths. Nuclear energy, released as a byproduct of the collision, may be the answer. Greenstein also pointed out that the very high velocities observed for filaments in the Cassiopeia A and Taurus A (Crab nebula) sources suggest nuclear reactions. A supernova explosion may well provide in many cases the trigger mechanism that ignites the nuclear processes.

All these theoretical considerations are still highly preliminary, but we came away from Jodrell Bank with the distinct impression that the ice of pure theory had been broken and that we are headed toward an understanding of the very high radio energies of some of the discrete sources.

This is the view along one arm of the Mills cross pictured opposite.

A Variable Radio Source

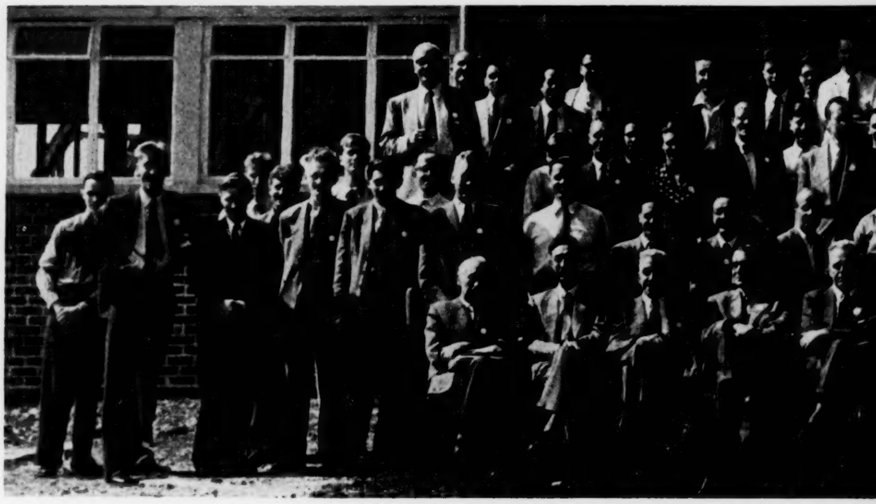
A very significant but as yet not understood observation of the first truly variable radio source was described by John C. Bolton, of California Institute of Technology, on behalf of O. B. Slee, of Sydney. The latter has found the radio source Hydra A to be variable with a period of six to 24 hours and with variations as high as 75 per cent of its total intensity.

Do not ask yet what this may mean—just be sure that a new and fruitful field of research has been opened up by this latest Australian discovery.

The General Background Emission

Toward the end of our second day, we came to the somewhat confused problem of the observed general galactic and extragalactic background radio emission. Most of the earlier surveys of the sky were made with instruments of low angular resolving power that were not really capable

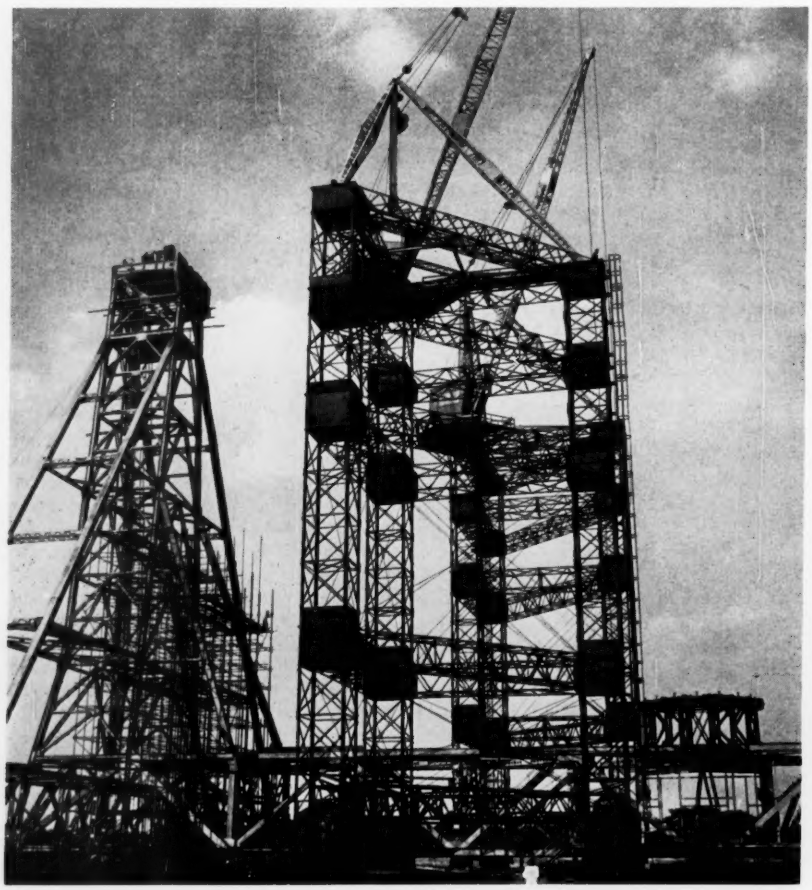
of giving the full picture. Modern techniques and larger antennas now make possible high-resolution surveys. R. Hanbury Brown, of the Jodrell Bank staff, pointed out in his introductory talk that the earlier surveys had suggested the presence of three principal components: thermal radiation from ionized gas, a distribution of discrete radio sources in our galaxy, and an isotropic component, at first thought to be of extragalactic origin. With increased knowledge, it appears more and more likely that the isotropic component is for the greater part of galactic origin, a point of view expressed some years ago by Shklovsky. Furthermore, J. E. Baldwin demonstrated conclusively that the Andromeda nebula, M31, has a large circular "corona" that produces radio emission at 3.7 meters. If a corona of this sort, which envelops all the known optical features of the Andromeda nebula, exists in our own galaxy, then it might well produce most of the observed isotropic component.



Radio astronomers at the Jodrell Bank Experiment

At present we have to think in terms of four superposed components: 1. Strongly concentrated to the Milky Way circle and caused principally by the thermal radiation from interstellar gas (though it is somewhat of a mystery why this type of radiation is so very intense from precisely the direction of the center of the galaxy). 2. Strong radio radiation originating mostly within 15 degrees of the galactic circle. 3. The galactic spherical or "corona" component. 4. Some general extragalactic component, caused by the superposed radio radiation from numberless faint distant galaxies.

The real puzzle at the moment is whence come the contributions listed as items 2 and 3. Are these from thousands upon thousands of individually rather weak radio sources? Do Unsold's flare-type dwarf stars here play an important role? How does the work on the background tie in with Ryle's result from the Cavendish survey, of a very uniform distribution over the sky of the fainter sources? These and similar questions were raised at the Jodrell Bank symposium, but they were not answered.



At the left is one pedestal of the 250-foot radio telescope, as it looked in August, with the erecting cranes in the middle. In the lower right is the central pivot around which both pedestals move.

Radio Studies of the Sun

On the morning of the third day, devoted to solar radio research, there were many reports of good progress in observing, but few really new or unexpected developments. The excitement and arguments came later when the theorists had their say on the observational papers.

The session began with a survey paper by C. W. Allen, of London University, who stressed the rather preliminary nature of our knowledge of existing models of the solar atmosphere, which are needed to interpret even the most general radio phenomena of the sun. This view was echoed by R. N. Thomas, Harvard Observatory, who believes that to understand eclipse and radio data we must assume the presence of hot elements (spicules) interspersed among colder elements. He suggested that, at a 1,500-kilometer height in the solar atmosphere, temperatures might be of the order of 15,000° to 30,000° absolute for the hot elements, against 6,500° to 9,000° for the colder ones.

The blue ribbon for the solar session should go to the Sydney observers. Pawsey presented corroborating evidence for

Station, University of Manchester, England, August 25-27, 1955. Photograph by Janet Cooke.

differences of brightness distribution over the sun's surface depending upon the line along which this distribution is traced, with quite different results for east-west and north-south lines. With his "dynamic spectrum technique," J. P. Wild can follow a disturbance right from the lower chromosphere into the upper corona. Of special interest are the bursts that move outward with speeds as high as one fifth the velocity of light. These bursts often come in clusters, and they are apparently associated with the origin of solar cosmic rays. Helen W. Dodson, of the University of Michigan, has noted that generally the radio and cosmic ray phenomena are related to the ending of the corresponding visual phenomenon on the sun, a solar flare.

There were many reports of radio eclipse studies, including work reported in person by V. V. Vitkevitch and B. M. Tchikhatchev, of Moscow. With low angular resolution still plaguing the radio astronomer, we are indeed fortunate that the moon eclipses the visible sun at regular intervals and that the Crab nebula is so placed that it is eclipsed by the sun and moon. All we need now for greater reliability at longer wave lengths is three or four extra moons in the sky, graded from the size of our present moon to several times its diameter.

T. Hatanaka, of Tokyo University, reported his observations of six components of polarization in the sun's radiation bursts at a frequency of 200 megacycles. A complete set of observations is obtained in 1/200 second. The polarization effects are remarkably strong and consistent, with very high percentage polarization observed on some days.

The principal theoretical papers were those of D. H. Menzel, Harvard; K. O. Kiepenheuer, Fraunhofer Institute; L. Biermann and A. Schlueter, Max Planck Institute. In three of these four papers the sun's magnetic field and disturbances in the field play a critical role. There seems little doubt that magnetic effects are basic in regulating the movements of solar disturbances and in producing the associated radio emission and cosmic rays. The precise nature of the processes involved is still very uncertain.

Solar System Problems

The final afternoon was devoted to radio studies of meteors, the moon, and the planet Jupiter. Fred L. Whipple, Harvard Observatory, gave the introductory talk, dealing principally with the physical properties of meteors. Considerable evidence indicates that meteors are porous affairs with average densities not exceeding 1/20 gram per cubic centimeter. In the discussion that followed Whipple's presentation, T. Gold pointed out that this means almost certainly that a meteor is a mass of thin needles and that the average meteor may really be something like a snowball and not at all like the familiar meteorites.

J. G. Davies and C. Gill reported on the fine work on radio meteors being done at Jodrell Bank under Dr. Lovell. With a new technique of radar echoes, radiant points and velocities of individual meteors were determined for 2,500 sporadic meteors during 12 periods of observation, each of 24 hours duration. The limiting brightness is about apparent magnitude 7 or 8, far fainter than the photographic and routine visual limits for meteors. No certain hyperbolic meteors have been found, and about 40 per cent of the fainter meteors move in orbits of low eccentricity with periods of the order of a year. High inclinations to the ecliptic are apparently common for these faint meteors.

The radio noise from Jupiter discovered at the Carnegie Institution early this year (see *Sky and Telescope*, June, 1955, page 324) has now been confirmed in Australia. C. A. Shain re-examined his 1950-51 records and found that for a period of two months the radio bursts were almost wholly restricted to times when one of the spots on Jupiter was facing the earth. The spot was identified by means of drawings by members of the Jupiter section of the British Astronomical Association. The Jovian thunderstorm outbursts, or whatever they may be, are exceedingly powerful, at least a billion times as strong as radiation from lightning in terrestrial thunderstorms.

The Jodrell Bank symposium was considered highly successful by all concerned, so much so that at the Dublin meeting following it plans were laid for a week-long symposium to be held (probably in France) prior to the 1958 assembly of the International Astronomical Union in Moscow.

This is one of the moving trucks that support the massive pedestals of the 250-foot radio telescope. These trucks carry the mounting on large circular tracks, providing for motion in azimuth. Photograph by the author.

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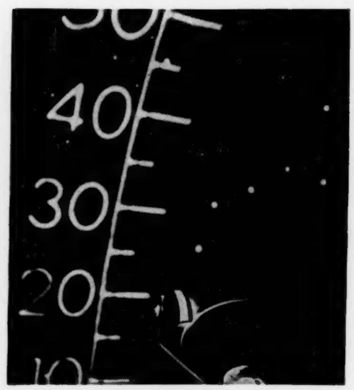

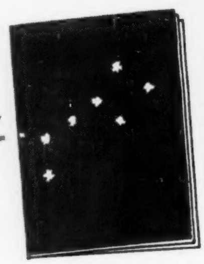

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BOOKS AND THE SKY

THE EARTH AS A PLANET

Gerard P. Kuiper, editor. University of Chicago Press, Chicago, 1954. 751 pages. $12.50.

THIS is the second of four comprehensive volumes on the solar system to be published. The subject of the first was the sun. The new volume has been eagerly awaited by scientists desirous of better co-ordination between earth sciences and astronomy. Detailed and accurate knowledge of the earth's interior, crust, oceans, and atmosphere, and understanding of its dimensions and motions will be invaluable to astronomers investigating the nature, origin, and evolution of the solar system.

Consisting of 15 separate articles under the editorship of Gerard P. Kuiper, of Yerkes and McDonald Observatories, the book is an attempt to systematize these aspects of earth science. The titles of the individual chapters merit listing, along with their respective authors, each of whom is an internationally recognized authority on his subject:

"Dimensions and Rotation," H. S. Jones; "Dynamics of the Earth-Moon System," H. Jeffreys; "The Interior of the Earth," E. Bullard; "The Development and Structure of the Crust," J. T. Wilson; "Oceanography," H. U. Sverdrup; "The Geochemistry of the Crust," B. Mason; "The Atmosphere Up to 30 Kilometers," H. R. Byers; "The Biochemistry of the Terrestrial Atmosphere," G. E. Hutchinson; "The Absorption Spectrum of the Atmosphere," L. Goldberg; "Density, Pressure, and Temperature Data above 30 Kilometers," F. L. Whipple; "Emission Spectra of Twilight, Night Sky, and Aurorae," J. W. Chamberlain and A. B. Meinel; "The Physics of the Upper Atmosphere," D. R. Bates; "Dynamic Effects in the High Atmosphere," M. Nicolet; "The Earth as Seen from Outside the Atmosphere," C. T. Holliday, and "Albedo, Color, and Polarization of the Earth," A. Danjon.

Because of the large amount of work required to produce such a book, one may well ask, "How well does it fulfill its purpose?" The purpose is explicit—to systematize useful knowledge and to make available a complete reference work. The usefulness of such a book depends on the editor's care in selecting the authors and his ability to co-ordinate their various review articles. Scientific information—good and bad—is being published at a really astounding rate. There is a clear and definite need for review articles to make useful information readily available and to create better liaison between specialized but related fields of science.

In those articles dealing with the earth's dimensions, dynamics, interior, hydrosphere, and atmosphere, editor and authors have achieved a generally competent and balanced synthesis of the present status of these related studies. These articles make up by far the largest portion of the book.

The chapter by Bullard is an excellent example of a useful survey article. In it is presented a critical evaluation of the present state of our factual knowledge (or ignorance) of the earth's interior, and an attempt is made to evaluate the various hypotheses at present in vogue. A summarizer can do no more. This article and many others in the book can be read and used with confidence by scientists crossing research boundaries from their own specialized fields.

However, it is the opinion of the present writers that two articles dealing with the geochemistry and development and origin of the earth's crust are not fully representative of current geological opinion.

Brian Mason's account is a condensation of his recent book, *The Principles of Geochemistry* (John Wiley and Sons, 1952). Criticism of this otherwise excellent survey of geochemistry lies in its omissions; many important aspects of this rapidly expanding branch of geology have been neglected in the condensation. Such important subjects as the application of thermodynamics and thermochemistry to

geochemical problems, and nuclear or isotope geology, deserve more complete treatment.

The treatment of the development and structure of the crust is inadequate. This chapter is biased in favor of one hypothesis, which is far from being universally accepted by geologists and geophysicists. Many other equally valid and interesting hypotheses either are too briefly mentioned or neglected, and are not critically evaluated. Nevertheless, Professor Wilson's account, presented in a convincing, well-organized style, contains an excellent listing of pertinent literature, and is one of the better-written parts of the book.

Establishment of an absolute, or even relative, geochronological scale is a recognized basic necessity for all theories of origin and evolution of the earth and solar system. The book, *Earth as a Planet*, does not critically discuss this important subject. Various brief references are made to age measurements in several of the articles, and on page 206 is presented an oversimplified geologic time scale. This scale is not new; it has been useful and the ages unquestionably are of the right order of magnitude, but it has been quoted too literally by some authors of astronomical and geological textbooks without any qualification as to its approximateness. For example, the placing of the base of the Paleozoic at 500 million years ago is not based on conclusive data, but almost on a single difficult measurement with a large possible error in accuracy. Also, for example, the "oldest rocks" mentioned were measured by the rubidium-strontium method and may be in error by as much as 30 per cent, because of the uncertainty in the radioactive decay constant of rubidium 87.

The treatment of the behavior of materials at elevated pressures and temperatures, which has been investigated by Bridgman, Birch, Griggs, Kennedy, Yoder, and others, is incomplete. These investigations are of great interest to those studying planetary structures.

Undoubtedly many readers will be introduced (as were the reviewers) to new fields of research by this book. The chapter on the biochemistry of the terrestrial atmosphere was found especially readable and enlightening.

There has been much speculation and considerable serious research work on the problem of life on other planets. It is felt by the writers that a survey of paleontology, evolution, and the origin of life, should have a place in *The Earth as a Planet.*

Most of the approaches to solving the exceedingly complex problem of earth and solar system origin have been made from the dynamical point of view. In recent years Chicago's Harold C. Urey has approached the subject from the chemical point of view, and has made many interesting and stimulating suggestions concerning the early protoplanet stage in earth history. Both he and the large number of excellent students he has trained have made significant contributions to this field of cosmology. The thermochemical view is a new and encouraging approach. Although Dr. Hutchinson discusses several of Urey's ideas on pregeological atmospheric conditions, Urey and his school deserve more space in *The Earth as a Planet.* Perhaps these aspects of cosmology will be included in the forthcoming two volumes on *The Planets*, and this may be a more appropriate place than in the present volume.

Each chapter contains a good and up-to-date bibliography, which would be more useful if titles were included in the references. Of course, this would increase the length of the book. It is adequately illustrated throughout with tables, diagrams, and photographs.

Some readers of *Sky and Telescope* will want to know if this book is written at an understandable level for the general reader. It is of professional level and is in no sense a text. However, most of the articles can be read and understood by anyone who has a good basic grounding in the physical sciences. The final chapter will be of special interest to many amateur astronomers, as well as to professional scientists.

Since the book will undoubtedly be widely used as a reference, especially by astronomers, it is unfortunate that it is

not entirely representative of current geological knowledge and opinions. It is hoped that in new editions a more thorough treatment will be given to the crust of the earth.

WILLIAM H. PINSON, JR.
and DAVID ROSTOKER
Massachusetts Institute of Technology

NEW BOOKS RECEIVED

CLIMATES IN MINIATURE, *T. Bedford Franklin*, 1955, *Philosophical Library*. 137 pages. $3.75.

As the subtitle, *A Study of Micro-Climate and Environment*, suggests, this book explores in popular language how the climate of a limited area, like a back yard or a hilltop, is influenced by vegetation and terrain. Although Mr. Franklin writes primarily as a naturalist and gardener, the amateur astronomer may pick up some ideas on what kinds of observing sites will be least subject to poor seeing and dew.

RADIO ASTRONOMY, *J. L. Pawsey* and *R. N. Bracewell*, 1955, *Oxford*. 361 pages and 23 plates. $8.80.

A comprehensive account of radio astronomy, written primarily for physicists and astronomers.

APPARENT PLACES OF FUNDAMENTAL STARS 1956, 1955. *Her Majesty's Stationery Office*, York House, London W.C. 2. 536 pages. £2 2s.

This volume contains the apparent right ascensions and declinations during 1956 of 1,535 stars, mostly brighter than 5th magnitude. The co-ordinates are given at 10-day intervals to $0^s.001$ and $0''.01$, respectively; for circumpolar stars, at daily intervals, and with right ascensions to $0^s.01$. Under the auspices of the International Astronomical Union, the American, British, French, Russian, Spanish, and West German almanac offices have shared in the preparation of this work, which is invaluable to the positional astronomer and the geodesist. The present volume is the 16th of the series.

WILLIAM HERSCHEL, *J. B. Sidgwick*, 1955, *Macmillan*. 228 pages. $2.50.

The life story of the greatest astronomical observer of modern times is told by Mr. Sidgwick. Although the work is for the general reader, there is much detail about Herschel's instruments and how he made them, and about his discoveries concerning planets, double stars, clusters, and nebulae. This book was first published in 1953 in England.

PRINCIPES FONDAMENTAUX DE CLASSIFICATION STELLAIRE, 1955, *Centre National de la Recherche Scientifique*, 45 Rue d'Ulm, Paris 5, France. 190 pages. 1,200 fr.

This is a collection of the papers presented at the 1953 Paris colloquium on the classification of stellar spectra, which was attended by astronomers from seven European countries and the United States. The topics discussed include new methods of spectral classification, the abundances of chemical elements in the stars, and stellar populations; the treatment is primarily directed to the specialist. No indication is given of the name of the editor of this volume.

ASTRONOMISCHER JAHRESBERICHT, Vol. 52, 1955, *Astronomische Rechen-Institut*, Grabengasse 14, Heidelberg, Germany. 454 pages. DM 50, paper bound.

The current installment of one of the most valuable of astronomical reference books, this volume is a listing of the astronomical literature published during 1952. The titles are arranged by subject, and all important article references are accompanied by a short abstract in German.

SOLAR ENERGY RESEARCH, edited by *Farrington Daniels* and *John A. Duffie*, 1955, *University of Wisconsin Press*. 290 pages. $4.00.

How the energy of solar radiation can be utilized practically was the subject of a symposium held in 1953 by the University of Wisconsin. This volume contains 37 papers contributed at the meeting on aspects as varied as house heating and the commercial use of algae to trap solar energy. There is an extended bibliography, and a list of all U. S. patents relating to utilization of solar energy from 1852 to 1954.

AMATEUR ASTRONOMER'S HANDBOOK, *J. B. Sidgwick*, 1955, *Macmillan*. 580 pages. $12.50.

This reference book for the advanced amateur explains the operation, use, and testing of reflectors and refractors; astronomical photography; micrometers and other accessories; and much other background information. There is an extensive bibliography. A forthcoming companion work is entitled, *Observational Astronomy for Amateurs*.

FRONTIERS OF ASTRONOMY, *Fred Hoyle*, 1955, *Harper*. 360 pages. $5.00.

A well-known British astronomer tells, in semipopular fashion, of many of the recently solved and still only partly solved problems of astronomy. These range from the origin of lunar craters to stellar evolution and the observational tests for the expansion of the universe.

DIE SONNENFINSTERNIS AM 30. JUNI 1954, *G. Skeib*, editor, 1955, *Akademie-Verlag*, Mohrenstrasse 39, Berlin W 8. 32 pages. DM 4, paper bound.

"The Solar Eclipse of June 30, 1954," reports measurements of solar radiation made at the Potsdam meteorological observatory and a branch station, as well as a study of radio transmission during the eclipse.

'SOUND BARRIER,' *Neville Duke* and *Edward Lanchbery*, 1955, *Philosophical Library*. 129 pages. $4.75.

This is a new edition of a popular account of jet aircraft first published in 1953. It deals primarily with British developments.

SILVER DOMES, A Directory of the Observatories of the World, *Claire Inch Moyer*, 1955, *Big Mountain Press*, 2679 S. York St., Denver 10, Colo. 174 pages. $6.00.

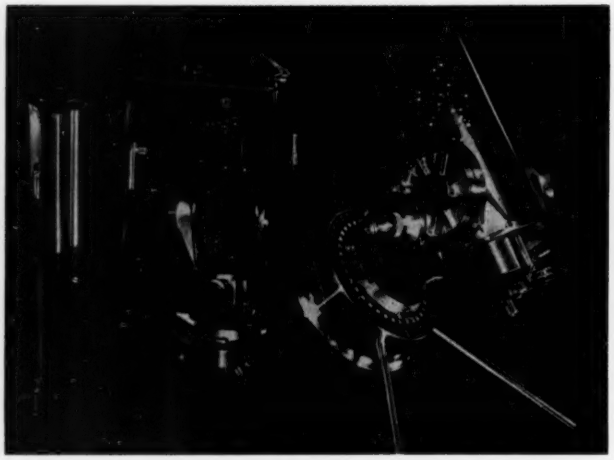
Descriptions of 132 observatories include historical information, lists of telescopes, and material on the scientific activities at these institutions. The sources of information are given for each article. Some accounts are based directly upon statements furnished by the institutions concerned. In other cases, the data are old, or the emphasis is wrong. There is a large proportion of incorrect spellings of names and places.

PERIODICITY AND VARIATION OF SOLAR (AND LUNAR) ECLIPSES, *G. van den Bergh*, 1955, *H. D. Tjeenk Willink & Zoon*, Haarlem, Netherlands. 2 volumes: 263 text pages, and portfolio of charts. $30.00.

Prof. van den Bergh, of Amsterdam, discusses the repetition of eclipses in great detail. Many eclipse cycles besides the well-known saros are treated. Large folding charts summarize the course of these cycles up to and past A. D. 3800. Oppolzer's lists of 8,000 solar and 5,200 lunar eclipses are reprinted in condensed form.

AMATEUR TELESCOPE MAKING—BOOK ONE, *Albert G. Ingalls*, editor, 4th edition, 1955, *Scientific American*. 497 pages. $5.00.

This is the fourth edition of a standard manual for amateur telescope makers. At the end of the book is a new chapter, giving simplified instructions for the beginner who wishes to make a first telescope without having to master such complications as the Foucault test.



To the right and on the opposite page are reprinted the first six pages of the Questar booklet. More will follow in succeeding advertisements. The entire booklet is available upon request.

WE'VE BEEN TELLING YOU

When we wrote the booklet Questar had not yet been marketed. We knew that Questar was good, we knew it would outperform any telescope of the same aperture anywhere, at any time. When we first undertook to make a compound telescope, we knew it would be difficult. That's why none at all had been offered for sale. Nobody made them. We knew that ultra-precision would be necessary, that its mirror must be accurate to 1/64 wave length instead of the 1/4 wave length that suffices for ordinary telescopes. We knew that the final result would depend on the painstaking matching of all optical components, and that to achieve such superlative quality would be time-consuming and costly. But we also knew that the final result would be worth it, and that the performance of such an instrument would be no less than an optical miracle. In writing the booklet we tried to restrain our enthusiasm, yet at the same time tell you all the things Questar could do for you while it freed you from the limitations of old-fashioned single-purpose telescopes.

NOW YOU'RE TELLING US

Questars are now in the hands of delighted owners in many parts of the world. They tell us we have been too conservative in our advertising, and that the instrument is more beautiful than the pictures indicate. They tell us they have never had so much fun with any optical instrument. Since owning a telescope no longer confined to the night skies, they are seeing beauty in nature they never knew existed. We are told it often outperforms telescopes of larger aperture. We are told it is ideal for variable star work, and that solar observers are seeing more sunspots with Questar's remarkable new conception in solar filters. Photographers are astonished at the power of their 42" telephoto lens, the cost of which is but a fraction of the price of unmounted competitive products. Industry has now found, as we expected it would, new and important uses for Questar's exquisite resolving power.

MAYBE YOU'RE MISSING SOMETHING

We suspect many people are missing a lot of fun because they have not yet used the most versatile telescope in the world. Perhaps you yourself do not fully realize how Questar's many features can add to your enjoyment. If you are just plain tired of setting up and taking down and hauling around your own conventional telescope, let us remind you that many people buy Questar for that reason alone. Now that Questar's reputation is firmly established, why not become a Questar owner yourself? Each instrument is unconditionally guaranteed. We urge you to read in the following columns more about Questar's many points of superiority. We suggest you reserve a Questar soon, because we cannot long guarantee its price at $795 in the face of steadily rising costs.

QUESTAR CORPORATION
NEW HOPE, PENNSYLVANIA

Questar

QUESTAR is a beautiful, compact 20th century telescope of great power and versatility. Its superb new optical system embodies the first basic discovery in telescope optics for 200 years. These optics belong to the new family of catadioptric or mixed lens-and-mirror systems, which permit Questar to compress, by optical folding, a full-sized 3.5 inch astronomical telescope of 7-foot focal length into a sealed tube only 8 inches long.

All Questar's advantages stem from this ultra-compactness of its unique design, for it is only one-tenth the size and weight of conventional telescopes of similar optical power. Thus Questar may be said to have freed the telescope from the traditional 18th century form in which it has been frozen, and lifted from the telescope the ancient burden of sheer bulk and weight that has made it so awkward to set up and use, and so difficult to carry and store.

Eight years of research and development have served to perfect the long list of patented improvements that distinguish Questar from its predecessors. The happy result is that Questar is not one, but several instruments. It does many things superbly well. It does them so easily and conveniently that you will probably wonder why someone had not thought to build such an instrument before. The answer, of course, is that it was not possible to do so until the new lens-mirror optics were discovered. Only then could the old dream of a little giant, a mighty midget of telescopes, at last come true.

Now Questar is at hand. You will find it more fun to use than any telescope in history. If you are considering the purchase of a telescope, we think that Questar is the one you should buy, because we honestly believe it to be the most rewarding all-round instrument obtainable. We believe that you will probably keep your Questar no matter what other instruments your purse may ultimately afford, for no other telescope can provide so much entertainment to your family and yourself over the years.

Questar's price is $795, complete in velvet-lined cowhide fitted case, with all accessories. Your check or money order for $200 will reserve your instrument, with balance C.O.D. Shipped in metal and fiber Leverpak drum containers by Express Collect. Questar Corporation, New Hope, Pennsylvania.

In this booklet we propose to tell you in detail about Questar and what it can do, with some brief notes on the history of telescopes, the care of fine optical surfaces, and a section on what to expect of a small telescope. We hope some of this may prove interesting or useful, and we beg forgiveness if we have been either too technical or not technical enough.

Questar is:

1. A complete portable observatory,
2. The first safe and distortionless solar telescope,
3. A perfect telephoto lens,
4. A superb terrestrial and spotting scope,
5. The new long-distance microscope.

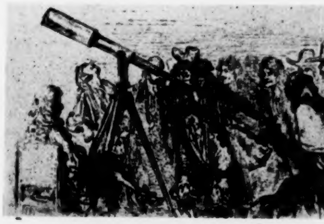
The Portable Observatory
—in one-half cubic foot

Questar comes in a beautiful velvet-lined fitted leather case of first quality, whose color, a deep maroon, serves well to set off the blue and silver instrument. Individual leather pockets grouped on the door panel hold all accessories.

The 7-inch rim of Questar's base slides under guides that hold it to the floor of the case, so that it travels free-standing, fully protected, while touching only the floor itself. Since it cannot touch anywhere else, no chafed holes or shabby spots will develop. Nothing projects beyond the 7-inch base circle, when the barrel is held rigidly vertical by its clamp in altitude.

Until now, conventional instruments large enough for serious work have had to be dismantled from 5-foot tripods, disassembled into several parts and stowed in great coffin-like wooden boxes which finally could be lugged about. Only those who have put up with the nuisance of unlimbering and setting up a traditional telescope can fully appreciate the wonderful convenience of Questar, which needs no assembly at all and is always ready for instant use. Only those who have staggered forth into the night with eight feet of assembled telescope tube and tripod legs can fully appreciate Questar's tiny size and feather lightness. Questar in its case complete weighs less than 12 pounds, and the case measures but 7½ x 8 x 15 inches, or one-half cubic foot. The problem of where to store a cumbersome instrument now ceases to exist. The amateur no longer need impose a large apparatus upon the family living space. Schools no longer need think of astronomy in terms of costly rotary domes to house traditional instruments, when even the smallest school can now afford to keep an observatory on its microscope shelf. We hope

to interest schools in the idea of acquiring Questar as a community project, so that everyone, young and old, may have the unforgettable experience of direct high power observation of celestial objects, for which there is no substitute.



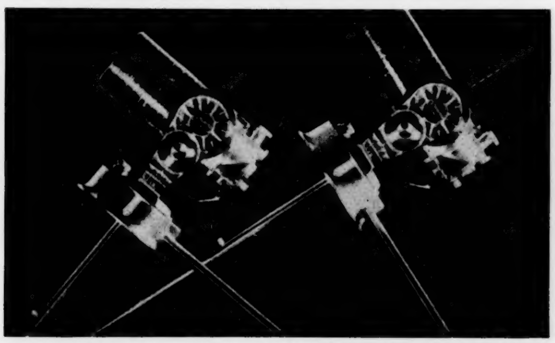
Woodcut after Gustave Doré

Questar slips out of its case all in one piece, ready for work. There is nothing to assemble. It is in its *altazimuth* form for general use, similar to the mounting on a surveyor's transit telescope, which points up and down in altitude and turns right and left in azimuth. Any convenient flat surface—tabletop, window-sill, wall top, shelf, or whatever is at hand, may serve as base for impromptu observing. Remarkable flexibility is afforded by Questar's unique rotating barrel, which inclines the eyepiece to meet the user's eye at any angle, permitting the instrument to be comfortably used without strain from many unusual situations and placements.

At the suggestion of Mr. Wagner Schlesinger, Director of the Adler Planetarium in Chicago, provision has been made to mount Questar on any automobile. It attaches readily to a window glass, which then may be raised or lowered to the most convenient height. In this simple manner, the touring motorist may rapidly bring the full 160 diameters of Questar's magnification to bear upon whatever object, near or far, arouses his interest. Joining Questar's tiny mass to the great mass of the stationary car results in perfect solidity and steadiness of image.

Questar, in its *polar equatorial* form, combines all of its unique features to provide what is probably the most comfortable observing position so far discovered, thereby creating the precise conditions for the greatest sharpness of vision. The equatorial mounting used by all great telescopes is essentially only an altazimuth telescope tilted just enough to align one axis with the axis of the earth. The tilted axis becomes parallel with that imaginary line joining the earth's south and north poles around which the earth actually rotates.

The chief advantage of this polar equatorial mounting is that once a star is in the field of view it can be kept there and followed by a single adjustment. Another advantage is that setting circles may be used, for now the stars on charts, including Questar's chart, are seen to be described in declination, which is distance in degrees above or below the celestial equator, and right ascension, or movement due to the rotation of the earth in the passage of time. The numbers on the setting circles of the telescope now correspond to the coordinate numbers on the star chart.



Questar is tilted into its equatorial form by pushing three sturdy legs into the precision reamed holes provided in the engine-turned base casting. The instrument is in balance without the use of heavy counterweights. Its center of gravity is low, with concentration of weight in the base, and feet widespread for utmost stability. By this excellent geometry and simple but elegant means, Questar is elevated so that its eyepiece and controls are raised approximately one foot above the tabletop on which it stands.

Many advantages result from this basic new conception of a tabletop equatorial telescope. For example, chairs and tables are everywhere in the world, and being of nearly uniform height, will always present Questar's eyepiece and controls to the seated observer in the same normal and convenient way. The observer seats himself facing south. He may now study the sky above him by looking comfortably down, as into an inclined microscope.

In this easy posture, the observer is at rest, in the normal, easy attitude of study. His whole body is unstrained and relaxed, and the retina of his eye is being nourished without the hindrance of a bent or twisted neck. He may rest his elbows on the table, put chin in hand, or cover with palm his unused eye and shift about in easy fashion while observing for extended periods. No user of conventional instruments, which have not changed their form in two full centuries and are still made today in their eighteenth century patterns, has ever experienced this kind of comfort. With Questar the observer no longer need tire himself in strained, awkward, unnatural postures. He needs no stepladders nor sets of boxes nor adjustable chairs to alter his standing or seating height. He need not crane his neck to follow an eyepiece whose height and location change by several feet for different objects. He need not strain to reach a finder above his head somewhere in the dark, for at the flick of his finger, Questar's eyepiece itself becomes the finder eyepiece too, while eyepiece and controls can only vary their position by mere inches from his eye.

The center leg is adjustable, so that Questar's inclined axis may be pointed toward the north star, and the polar region, from any latitude from Canada to Mexico. This axis, which passes also through the adjustable leg, need only point to the general vicinity of Polaris, since the benefit of following a star in one smooth arc, which the polar equatorial mounting permits, instead of a series of zig-zag motions, does not depend on exact alignment to give splendid results. This leg is permanently assembled, so that no part of it could become accidentally lost, and all the legs have special rubber tips.

When facing south, the observer has the most interesting part of the sky before him, the part of greatest interest for visual work. Here are all the planets, the moon, the celestial equator, and ecliptic, from which the visible planets never stray by more than 9 degrees. With Questar's star chart, the major objects in the skies may be identified throughout the year, and details of the moon identified by the lunar chart. Naturally, too, a tabletop is the obvious place for notes and books of reference.

Unlike the shaky pendulous long tubes of conventional instruments, that tremble at the slightest touch or breeze, Questar's stiff short barrel is immovable, its period of oscillation very short, a fraction of a second. The result is that Questar's image is practically as sharp and steady as the image of a microscope. It is not blurred by constant needless motion. It does not commence to shiver the instant fingers touch the focussing knob, nor is that knob somewhere up above one's head; there is nothing to reach out for at arm's length.

The supreme touch of practical luxury is furnished by the built-in synchronous electric drive which keeps Questar pointing continuously at the same object in the sky. By precisely neutralizing the rotation of the earth, it keeps objects quite stationary in the field of view of the eyepiece.

Operating on 115 volt 60 cycle house current, the electric drive also actuates the engraved 6-inch right ascension circle, which thus becomes a sidereal clock reading to 4 minutes of time. The drive is smooth and imperceptible. It is free of falter, jump or backlash. It is nearly noiseless, is totally enclosed and its sealed gear train runs in oil, sufficient for a century of use. The special motor winding used was developed by Questar for the elimination of heat.

Liberated by this modern refinement from the necessity of manual following, the Questar owner is free to concentrate wholly upon observing and the problem of perception near the limit of vision. He will, of course, improve his visual abilities with practice, and will become better able to enjoy Questar's powers of resolution to the full.

Questar's outstanding performance is especially evident in observing planetary detail, possibly the most rewarding field for the amateur. It excels refracting telescopes of the same aperture by the complete absence of spurious color in the images, and it is superior to reflecting telescopes by its spiderless closed tube and the perfection of its images over a wide field.

The First Safe And Distortionless Solar Telescope

Since Galileo, men have tried to study details of the great sunspots that wax and wane, and wheel from day to day across the dazzling face of the nearest star, our sun. During his lifetime, the solar disc was viewed by projecting its image upon a white card or screen from the eyepiece of the telescope. This primitive method is lacking in sharpness, and the intense beam that must traverse the eyepiece lenses, although excellent for lighting cigarettes, quickly ruins the cemented doublets of modern highly corrected eyepieces by boiling out the cement. Thus, none but the eighteenth century eyepieces of Huygens or Ramsden types could be used, whose single lenses suffered less from heat.

The sun is best seen by direct observation. This method depends on some arrangement to keep the blinding light and heat from entering the observer's eye. Previous dispersion or absorption devices have always been applied near the very hot "burning glass" image of the sun at the focal point of telescopes. Not many astronomers ever thought to diminish the solar radiation save *after* it had passed through most of the instrument, warping lenses or mirrors, heating trapped air within the tube, and sometimes damaging not only eyepieces, but observer's eyes as well, for dark-glass filters have been known to break from heat.

It has remained for Questar to produce a simple filter which keeps the harmful concentration of heat from entering the telescope at all. It completely shields the instrument from all the solar radiation, except one part out of fifty thousand. Questar's solar filter consists of a measured thickness of chromium metal deposited on glass, which is placed over the front lens. It rejects the sun's radiation by reflecting it away instead

(TO BE CONTINUED)

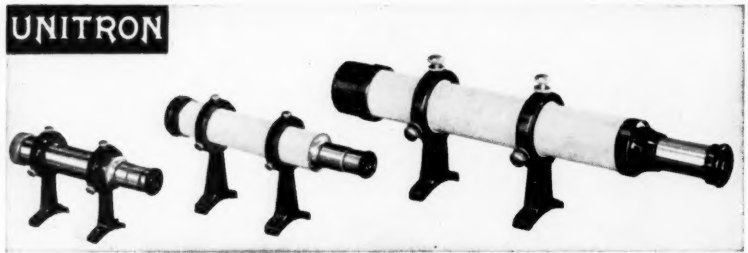
Modernize Your Telescope with Components by UNITRON

UNITRON accessories are standard equipment in UNITRONS themselves and are, therefore, of the finest quality and workmanship. We are proud that so many well-known observatories throughout the world have added these components to their telescopes. Here are gifts to delight any astronomer on your Christmas list.

UNIHEX Rotary Eyepiece Selector

The old-fashioned method of fumbling with eyepieces in the dark has been outmoded by UNIHEX, UNITRON's new Rotary Eyepiece Selector. With UNIHEX, you always have 6 magnifications ready at your fingertips. To change power, merely rotate a new eyepiece into position while the object stays centered and in focus in the field of view. Model A is designed to fit the UNITRON rack and pinion and is for UNITRONS only. Model B fits 1¼" eyepiece holders. Complete with special clamping device and cabinet. (Illustrated on back cover.) A or B:

Only $24.75 postpaid



L. to R.: (1) 23.5-mm. 6x finder; (2) 30-mm. 8x finder; (3) 42-mm. 10x finder

1. VIEW FINDER (As used on UNITRON 2.4" Equatorial): 23.5-mm. (.93") achromatic objective, 6x eyepiece with crosshairs. Chromed brass tube. Mounting brackets with centering screws.

Only $8.50 postpaid

2. VIEW FINDER (As used on UNITRON 3" Refractors): 30-mm. (1.2") coated achromatic objective and 8x eyepiece with crosshairs. Other details as in View Finder 3.

Only $10.75 postpaid

SUN PROJECTING SCREEN APPARATUS: White metal screen with matching black metal shade. Chromed brass extension rod with mounting brackets.

Set with screen 6" x 6" **Only $13.50 postpaid**

Set with screen 7" x 7" **Only $15.75 postpaid**

3. VIEW FINDER (As used on UNITRON 4" Refractors): 42-mm. (1.6") coated achromatic air-spaced objective. 10x eyepiece with crosshairs. Duraluminum tube finished in white enamel. Dewcap. Furnished with mounting brackets with centering screws for collimation. This finder also makes an excellent hand telescope for spectacular wide-field views of the sky.

Only $18.00 postpaid

EQUATORIAL MOUNTING and TRIPOD: Complete with slow-motion controls for both declination and R. A., setting circles and verniers, and many other features.

As used on UNITRON 3" Refractor	$198
As used on UNITRON 4" Refractor	$370

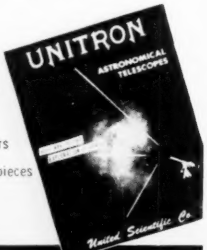
(These prices are f.o.b. Boston)

Get this FREE Buyer's Kit on UNITRON Astronomical Telescopes!

While you can't build a telescope with this "kit," you can obtain a good deal of information that will help you decide on the telescope most suitable for you. Included in this informative collection is the UNITRON catalog which describes and illustrates all models. A special section tells you how to choose a telescope. Read actual observation reports from UNITRON owners. This literature is required reading not for telescope buyers only but for all astronomers who want to find out more about the famous UNITRON Refractors.

Learn about—

- equatorial and altazimuth mountings
- objective lenses
- refractors and reflectors
- magnification and eyepieces
- accessories



United Scientific Co.

204-6 MILK STREET • BOSTON 9, MASS.

Please rush to me, free of charge, your "Buyer's Kit" on Unitron Astronomical Telescopes.

Name..

Street..

City.......................State...............

Here's the UNITRON "Tri-Power" 20x, 30x, 40x Terrestrial Telescope

The UNITRON 60-mm. "Tri-Power" is the ideal portable telescope for nature study, bird watching, vacation trips, sports events, viewing the moon, and for use whenever you want a real closeup view of a distant object.

With the new Triple Revolving Eyepiece Selector, the observer chooses the desired magnification of 20x, 30x, or 40x, by merely rotating an eyepiece turret. There is now no need to be restricted by a telescope with only a single power or to one with individually changeable, easily misplaced eyepieces. The telescope tube is made of lightweight duraluminum and finished in white enamel. With the large 60-mm. (2.4") coated objective, brilliant sharp images are obtained even with dim lighting. Focusing is easy and foolproof with the micromatic rack-and-pinion knob.

A sturdy three-section tripod and mounting is included — there is no need to buy this costly extra. The tripod adjusts in height from 30 to 62 inches, so it may be placed on a table for observation while sitting as well as standing. An altazimuth mounting makes it easy to move the telescope when following moving objects or for panorama views. The tube easily detaches from the tripod for storage or transport.

$59.95 postpaid

ASTRO-CAMERA 220 (Illustrated on back cover): With this camera, owners of altazimuth models can photograph the sun, sunspots, the moon, and solar and lunar eclipses. An equatorial model is required for recording other celestial objects which need longer exposures, and the clock drive is essential for prolonged tracking. The camera uses an air-operated curtain shutter of the Thornton-Pickard type, giving speeds of 1/10 to 1/90 second in addition to bulb and time. The camera may be positioned so that the plane of the film passes through the focal point of the objective, which is then the only optical element. When magnification of the primary image is desired, an eyepiece can be inserted into the camera tube and an image projected on the film. Astro-Camera 220 comes complete with ground-glass back, 3 double plateholders for 3¼" x 4¼" plates or cut film, a 30-mm. f.l. eyepiece, extension tubes and clamps, and a fitted wooden cabinet. Model A is designed to fit the UNITRON rack and pinion and is for UNITRONS only. Model B fits 1¼" eyepiece holders. Model A or B.

$69.50 postpaid

DUETRON Double Eyepiece (Illustrated on back cover): The new DUETRON double eyepiece literally doubles the usefulness of your UNITRON. Two observers may use the telescope simultaneously and with equal comfort. The two eyepiece holders may be turned independently with respect to the telescope tube to suit the convenience of each observer. A focusing sleeve is provided so that the eyepieces used need not necessarily be of the same magnification. DUETRON is a boon for father-and-son observing teams and for observers who buy their UNITRON in partnership, since it eliminates the need to take turns. With DUETRON, more observers may be accommodated at star parties, and the advanced members may provide valuable instruction to the beginners as they look through the UNITRON together. The DUETRON tube is interchangeable with the customary UNITRON drawtube and may be used with all models with the exception of the 1.6" Refractor.

$23.50 postpaid

PHOTOGRAPHIC GUIDE TELESCOPE: 62-mm. (2.4") diam., 700-mm. (27.5") focal length, coated, air-spaced, achromatic objective. 78x (9-mm.) achromatized Ramsden eyepiece with crosshairs. Star diagonal. Duraluminum tube finished in white. Dewcap. Rack-and-pinion focusing. Mounting brackets and centering screws for collimation. Fitted wooden cabinet.

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GLEANINGS FOR ATM's

EDITED BY EARLE B. BROWN

Notes on Basic Optics—XVI

P. Spherical Aberration

Some description of the spherical aberration of lenses was already given in the March, 1955, installment of this series. There it was shown how light rays entering a lens, parallel to the optical axis of the lens but at unequal distances from it, do not come to a common focus. It was also pointed out how we may "bend" a lens to vary its spherical aberration, without changing its equivalent focal length.

This section will discuss spherical aberration in more detail and will point out some of the methods for controlling it. However, for a full treatment one must turn to textbooks on optical design; we shall not lay all the groundwork necessary for a rigorous discussion.

1. **Longitudinal Spherical Aberration.** Consider a ray of light passing through a lens; its **intersection length** is the distance from the back surface of the lens to the intersection of this ray with the optical axis. We can define the longitudinal spherical aberration of a lens or lens system strictly: It is the difference in intersection lengths between a particular ray and the paraxial ray. (The latter ray, it will be recalled, defines the location of the paraxial image plane.) This aberration is positive if the ray in question falls short of the paraxial image plane. The result of the aberration is that the image of an axial point will be spread out along the axis.

Evidently, there is no single quantity that we can call the spherical aberration of the lens; there will be a different value for each ray. The longitudinal spherical

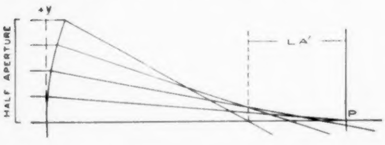


Fig. 50. LA′ represents the primary longitudinal spherical aberration.

aberration as computed for a ray at a particular height, y, in the aperture (Fig. 50) will not increase linearly with y. Rather, it may be shown mathematically that the value will follow an equation of the form,

$$S = ay^2 + by^4 + cy^6 \ldots \quad (34)$$

The spherical aberration may be divided into parts, as indicated by this equation. The first term, which varies as the square of y, is called the **primary spherical aberration,** and for a simple lens is by far the largest of the various terms.

The primary spherical aberration is greatest for a ray at the edge of the aperture, and thus we may say, to a close approximation, that primary spherical aberration varies with the square of the aperture of the lens.

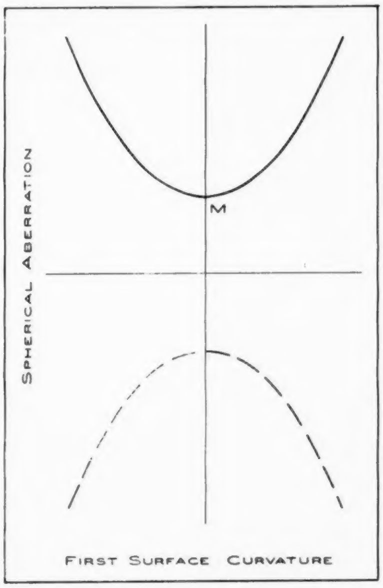


Fig. 51. The effect of lens curvature.

2. **Lens Bending.** As was mentioned, we can change the spherical aberration of a simple lens by "bending" it, that is, altering the distribution of curvature between the two surfaces. One naturally asks, "Is it therefore possible to make the spherical aberration of a single lens zero by bending?" The answer is no—with some qualifications.

In general, if the spherical aberration for a given value of the height y is plotted against various possible bendings, the graph will be a parabola, as in Fig. 51. The curve does not go to zero, but has a minimum at **M.** The upper curve is drawn for a positive lens, the lower dashed curve for a negative lens, which has negative spherical aberration.

It is clearly possible, in theory at least, to combine a positive and a negative lens so the total spherical aberration is zero. This is actually done with optical systems in general. The simplest case, and the one of most interest to astronomers, is the doublet lens, or achromat, consisting of a positive and a negative element.

As described in July, it is possible, for any choice of two different glasses for the two components, to find a distribution of curvature between the two lenses that will give zero primary chromatic aberration. By appropriate bending of

the same lenses, it is also possible to provide for zero primary spherical aberration. This does not change the chromatic correction.

There is, however, one difficulty. The primary spherical aberration can be corrected (brought to zero) for only a single value of y, the height in the aperture; for other values of y the correction is only partial. It is necessary to choose a y so the over-all correction is optimum. This will be the case when the extreme mar-

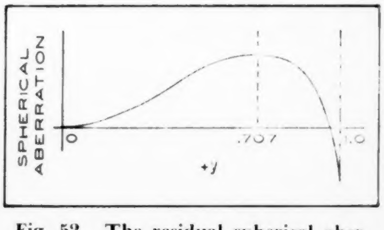


Fig. 52. The residual spherical aberration when primary spherical aberration is made zero for a marginal ray.

ginal ray from the edge of the aperture is brought to a common focus with the paraxial ray. When this is done, the remaining longitudinal spherical aberration, plotted against y, will give a curve of the form shown in Fig. 52. The peak of this curve corresponds to a ray for which y is 0.707 of the marginal height.

Nearly all optical systems have spherical aberration graphs similar to Fig. 52. The task of the optical designer is to make the peak as low as possible.

It is important to note that a lens system corrected for spherical aberration at one particular conjugate distance is not, in general, corrected for any other conjugate distance. A photographic lens, for example, excellently corrected for infinity, may perform very poorly when used for copying work, even with an extension bellows to take care of the increase in image distance. This is why it is so difficult to design variable magnification systems, such as zoom lenses. If it is necessary to maintain reasonable correction over a wide range of conjugate distances, a very complicated lens system is usually needed.

3. **Circle of Least Confusion.** Of chief concern in the image quality of an optical system is the spread of a point image in the focal plane, that is, perpendicular to the optical axis. How does spherical aberration affect the image in the focal plane?

Fig. 53 shows two lenses with equal longitudinal spherical aberration. In both cases there is a region where all the rays from the axial object point pass through a restricted area, indicated at S. This area is known as the circle of least confusion, and it is evident that the sharpest image will be obtained by focusing the eyepiece, or placing the photographic plate, at this point. The size of this circle is the true measure of

the seriousness of spherical aberration; it is obviously less in the upper of the two cases represented in Fig. 53.

The clue to the difference between these circles of least confusion is the relative aperture of the lens system (see May, 1954). Where the f/number is large, that is, in "slow" systems, large values of the longitudinal spherical aberration may exist without serious image deterioration. On the other hand, for "fast" systems, where the f/number is small, even a small value of longitudinal spherical aberration may be intolerable. For this reason lenses of large aperture are difficult to design unless they are of long focus—not only must the aberrations be corrected over a wider aperture, but the tolerances on the degree of correction are much tighter.

4. **Cases of Zero Spherical Aberration.** There are three cases for which the spherical aberration of a single refracting surface is zero. These are the qualifications mentioned in answering the question in section 2, all of them useful in optical design.

Case 1. When the object point lies at the center of curvature of the spherical refracting surface, the rays pass through the surface along a perpendicular, they are not bent, and therefore there can be no spherical aberration. In such a case, of course, the image is coincident with the object.

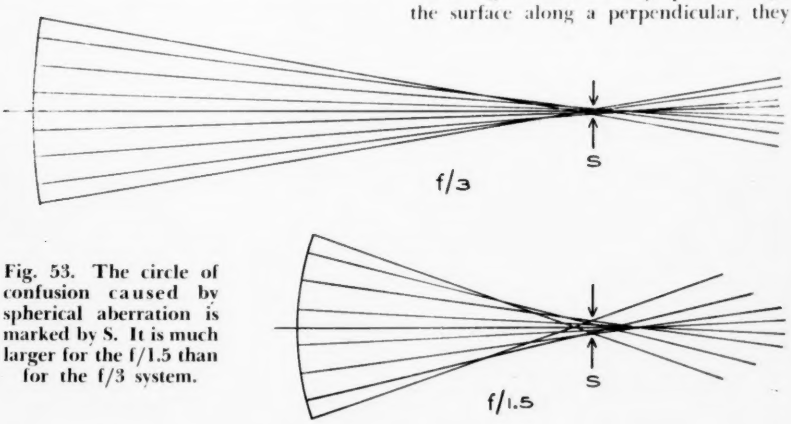


Fig. 53. The circle of confusion caused by spherical aberration is marked by S. It is much larger for the f/1.5 than for the f/3 system.

Case 2. When both object and image lie at the apex of the refracting surface, the rays pass through undeviated. This condition permits the use of field lenses without concern over their primary effect on the image quality.

Case 3. This case is of very great importance in optical design. It occurs when the ratio of the image and object distances for a refracting surface is equal to the inverse ratio of the indexes of refraction of the two media concerned, or

$$\mathbf{d/d' = n'/n}. \qquad (35)$$

This is called the **aplanatic condition,** and the points concerned are the aplanatic points of the surface in question. There is only one pair of such points for a given surface, since the values of **d** and **d'** depend upon the curvature of the surface. The condition is, of course, strictly true only for a pair of points on the optical axis, but the condition of freedom of spherical aberration is approximately maintained over a considerable distance from the optical axis.

The aplanatic condition is of considerable value in the design of microscope objectives, where images are transferred from one surface to the next, with an increase in magnification at each transfer.

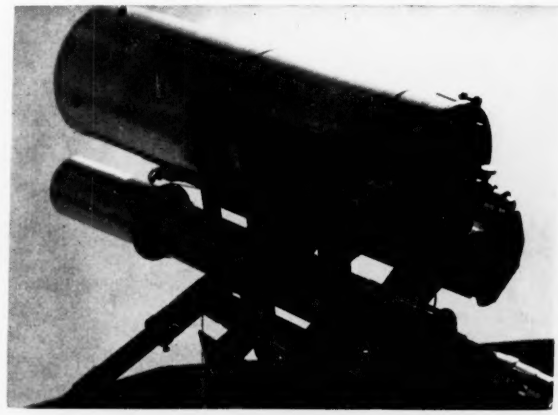
(To be continued)

A 10-INCH DALL-KIRKHAM TELESCOPE

ALTHOUGH I have long been a refractor-minded observer of variable stars, today I am the owner of a really fine 10-inch Dall-Kirkham telescope. Shortly after the war, when Wagn H. Hargbol, a Boston optical manufacturer, was here in Copenhagen, he was interested in my observational work, and later sent me a 4-inch Zeiss Aero triplet lens for photography. I mounted this on my 4½-inch Zeiss short-focus refractor, and use it to chart star fields of variables, and to locate faint comets. A 10- or 15-minute exposure is generally enough, and half an hour later I can locate the object visually.

Three years ago, Mr. Hargbol offered to make a set of Dall-Kirkham mirrors for me at nominal cost. At the advice of Prof. B. Stroemgren, now at Yerkes Observatory, we chose a 10-inch aperture and an equivalent focal length of four meters. Such a telescope would not be too small for photoelectric work, and it would be useful for visual and photographic observations of planetary details; at the same time, it would not be too hard to mount.

The mirrors crossed the Atlantic safely, but illness of both my collaborator, Mr. Rasmussen, and myself delayed completion of the tube and mounting until May of this year.



P. Darnell's astronomical battery consists of a 10-inch Dall-Kirkham reflector, below it a 4½-inch refractor, and beyond the 10-inch a 4-inch camera. These instruments are seen from in front in the picture opposite, where the reflector is on top, the 4-inch camera at the left below, and the 4½-inch refractor at the right.

The collimation was difficult for a novice. Astigmatism was the enemy. At last I had to rig up a special gadget to collimate the f/3.2 primary. Nearly parallel light from an illuminated cross was projected on the primary, and reflected onto ground glass placed just behind the focus of the primary. When the gadget was rotated on the end of the tube, the image of the bright cross would shift its position on the ground glass. We had to adjust the position of the primary mirror until the image would no longer move.

With good seeing, the telescope shows small, sharp star disks surrounded by several diffraction rings. Compared with stars in a fine 10-inch Zeiss refractor of the same focal length, the star disks are of the same size and quality, but naturally completely achromatic. Even during our rather bright summer nights, stars of about 14th magnitude are visible, thanks to a conical sky-fog baffle inside the telescope which gives a darker background and more contrast than usual in a Cassegrain. My miniature reflex camera is adapted to the telescope. By inserting a Barlow lens, a 16-meter focal length is obtained.

Another extremely useful accessory is a binocular eyepiece for lunar and planetary observing. The beam-splitting

Mr. Darnell's son peers past the 10-inch reflector.

prism does slightly reduce illumination, but you can see small detail better at 20 per cent less magnification than you can with one eye. The reason is physiological: visual perception is generally faster in binocular vision than in monocular. My own experience is that I can locate planetary detail more easily and time transits of Jupiter's spots better with binocular vision. Here is something to try on Mars in 1956. A rather inexpensive binocular attachment for microscopes can do the job.

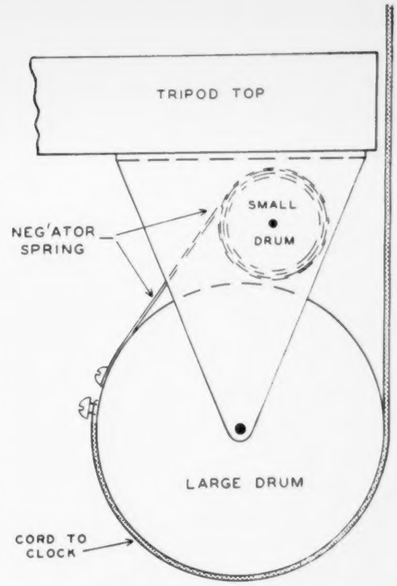
P. DARNELL
Ved Vandlobet 17
Bronshoj, Denmark

SPRING POWER FOR DRIVES

USING a weight to power a clock drive is fine for permanently mounted telescopes, but if the instrument is on a tripod, a spring-driven apparatus is better. But the particular type of spring is important—it should be one that has a constant rate and tension as it runs down. Here I wish to describe a spring that has this characteristic, and which has been added to my alarm-clock drive described in April, 1954.

The trade name of this spring is Neg'ator, and it is made in various sizes by the Hunter Spring Co., Lansdale, Pa. It is like a clock spring, except that instead of opening up when released, it closes down with each coil tight against the one under it. It does this because every part of the steel strip has been bent to the same radius, giving a "spring rate" of zero.

Therefore, with a Neg'ator spring it is possible to make a spring motor that exerts a constant force, as a weight does. The drawing shows the condition when the spring is run down. As the clock drive is wound up, the cord to the clock unwinds from the large drum, and at the same time the Neg'ator spring is pulled from the small drum and wrapped onto the large one. While the drive is operating, the spring tends to run from the large drum to the small. The tension on the cord varies approximately as the square of the difference in drum diameters. A hole must be made in one end of the spring to fasten it to the larger drum, but it is unnecessary to fasten the end on the small drum.



In the pictured arrangement, there is only about half a revolution of the larger drum available for each winding. If it is desirable to wind less frequently, the large drum could be made wide enough for the cord to wrap on beside the spring.

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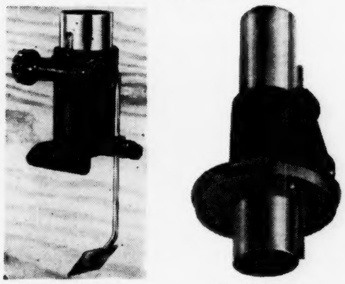

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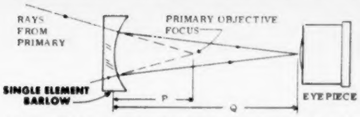

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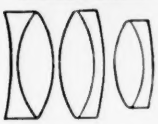

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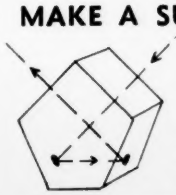

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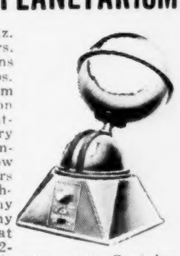

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OBSERVER'S PAGE

Universal time is used unless otherwise noted.

Cometary and Other Observations

REPORTS from amateurs indicate a busy summer, chiefly because of three relatively bright comets. But experiences in observing them varied considerably, as these excerpts show. First, Roger Cuffey, 522 Eastside Drive, Bloomington, Ind., writes:

"With my 3-inch, f/4.9 refractor, using a 17x eyepiece, Comet 1955e (Mrkos) was first seen by me on the morning of June 16th. It appeared of magnitude 5.5, with a tail about 20′ long. I followed it until August 8th, when its magnitude was 10.5 and it was 5′ in diameter, and the tail was gone. Comet 1955f (Bakharev-Macfarlane-Krienke) was watched from July 27th to August 25th, as it faded from 7th to 10th magnitude. On August 5th, when first seen, Comet 1955g (Honda) was also magnitude 7; my latest view of it was on September 15th, when it was magnitude 9."

G. R. Wright, 202 Piping Rock Drive, Silver Spring, Md., found Comet Mrkos very hard to locate on July 25th. He plotted what he thought might be it on a map, however, and later found the observation checked with the predicted position. Other members of the National Capital Astronomers who observed this comet were Lyle Johnson, Dana Law, and H. J. Walls. Mr. Johnson took some photographs of the object.

Stephen P. Maran, 500 St. John's Place, Brooklyn 38, N. Y., writes concerning observations of Comet Honda at the Stellafane telescope makers convention on August 20th:

"The comet's motion was quite rapid, considerable change in position occurring in an hour or more, and some slight shift with respect to the stars was perceptible during 15 minutes. The object was a hazy ellipse about 2/3° along the longest axis, and many observers were struck by its resemblance to a bright galaxy, such as M31. The individual parts of the comet were indistinguishable, and like such nebulae as the North America and M33, it seemed to suffer with increase in objective size as well as magnification."

Mr. Cuffey also reported two other difficult observations: "The July 5th penumbral lunar eclipse was observed as a slight darkening of the moon's south limb from 5:12 to 5:32 UT. Venus was seen on August 31st at 15:00 UT and again on September 1st at 14:20. We used an 8-inch reflector at 74x, and the planet was about 70′ north of the sun's northern limb. I wonder if anyone else saw Venus at or near superior conjunction. It was first visible in the evening sky on September 11th, with both the 3-inch and the 8-inch telescopes."

PHOTOGRAPHING THE MOON

For a simple, effective method of photographing the moon, I have used a 28-mm. war-surplus Kellner eyepiece attached to my 6-inch f/8 Newtonian reflector, which is equatorially mounted. To the eyepiece holder I fitted a short adapter tube to attach an old Japanese Compur portrait camera. Both lenses of the camera were taken out, and the ground-glass back was used for focusing the eyepiece.

When the moon's image appeared sharp on the ground glass, a film-pack adapter was slipped into place, and the exposure made. This had to be done quickly, as my telescope has no drive. I use 1/25-second exposures on Kodak Super XX film and develop in Microdol. Shown here are contact prints made on Velox F-4 paper and developed in Dektol.

Frankly, I was pleasantly surprised at such good results with the simple equipment. I think that the quality of the eyepiece, which should have a large eye lens, is the key.

HERB BASSOW
3875 Waldo Ave.
New York 63, N. Y.

At the left is Herb Bassow's picture of the 9-day-old moon. On the right, the moon is 20 days old.

PHOTOELECTRIC MAGNITUDES OF PLEIADES STARS

Luc Secretan's description, on page 433 of the August issue, of his visual photometer and his measurements of the Pleiades interested me particularly, for three years ago I made some similar measurements of Pleiades stars to test my photoelectric photometer. I had to repeat the experiment in 1954, because meanwhile I broke my 1P21 photomultiplier tube by the simple expedient of dropping it on the floor. This cost me $50.00.

My experience, as an amateur in the northeastern states, is that atmospheric conditions are good enough on only about five nights per year to allow photoelectric measurements consistent within ± 0.005 magnitude. A scattering of several hundredths of a magnitude is not unusual.

The table shows what an amateur may expect. My observations were made with a 1P21 photomultiplier and a Kron amplifier; a Schott BG1 filter was used for blue magnitudes and a GG7 for yellow magnitudes. For comparison I give magnitudes determined photoelectrically by O. J. Eggen (who at Lick Observatory used Corning filters 5330 for blue light and 3385 for yellow), and by H. L. Johnson and W. W. Morgan (who used Corning 5030 plus Schott GG13 filters for blue light and Corning 3384 for yellow).

The agreement between my measurements and those of Johnson and Morgan is fairly good in the blue, but not so good in the yellow where ordinarily less trouble would be expected from atmospheric conditions. I do not know the reason for this, apart from the fact that different filters were used. When this was mentioned to Dr. John S. Hall, of the U. S. Naval Observatory, he remarked that perhaps I had a bug in my photometer which was fond of yellow; this seems as good an explanation as any.

STAR	BLUE LIGHT				YELLOW LIGHT			
	Eggen	*J. and M.*	*Ruiz 1952*	*Ruiz 1954*	*Eggen*	*J. and M.*	*Ruiz 1952*	*Ruiz 1954*
η Tau (Alcyone)	2.65	2.59	2.59	2.61	2.82	2.86	2.83	2.87
27 Tau (Atlas)	3.42	3.35	3.36	3.35	3.59	3.62	3.58	3.59
20 Tau (Maia)	3.66	3.61	3.58	3.63	3.82	3.86	3.83	3.88
23 Tau (Merope)	3.98	3.93	3.94	3.93	4.12	4.17	4.17	4.17
19 Tau (Taygeta)	4.05	4.00	3.94	4.00	4.23	4.29	4.27	4.30
28 Tau (Pleione)	4.93	4.83	4.82	4.79	5.07	5.09	5.06	5.03
16 Tau (Celaeno)	5.24	5.22	5.28	5.22	5.40	5.44	5.57	5.47

JOHN J. RUIZ
Dannemora, N. Y.

DEEP-SKY WONDERS

IN NOVEMBER clean polar air masses drift down over most of the United States, bringing some of the best nebular observing of the whole year. Try to observe just after a clear-cut cold front has passed swiftly over. Perhaps the first thing to look at is the great Andromeda galaxy, M31. Visually, it usually appears less than two degrees in length, but R. Jonckheere, with 2-inch binoculars and taking extreme precautions, finds it extends 5° 10′ (see page 397 of September, 1954). What do your observations show?

Next try to see M33 in Triangulum with the unaided eye; it can be done. Your finder will show this galaxy easily, but 100x on your telescope may lose it. After all, it is larger than the full moon. Near M33 is a pleasant open cluster of considerable richness. NGC 752, with a total magnitude of 7, is easily found at $1^h\ 54^m.7$, +37° 25′ (1950). Spread over a half-degree field, its more than 100 stars invite extended scrutiny.

Somewhat harder for small instruments, but within the reach of a 6-inch, is the galaxy NGC 772, at $1^h\ 56^m.6$, +18° 46′. It is a spiral 5′ by 3′ in angular size, of visual magnitude about 11.

For a severe test of the largest and the best of amateur instruments (does this include yours?), try the quadruplet galaxies NGC 703, 704, 705, and 708. For some reason NGC 703 is plotted in Nor-

ton's atlas, but they are all very, very faint. I have seen them with a 16-inch refractor, with 703 being slightly brighter. Its position is $1^h\ 49^m.7$, $+35°\ 56'$, and the others lie within 3′ to the south and east.

Now test the optical perfection of your lens: turn down through Cetus to Gamma (γ). This is the double star ADS 2080, Struve 299, lying at $2^h\ 40^m.7$, $+\ 3°\ 02'$. A 5-inch will show the companion readily, in position angle about 293°, and distance three seconds. The widely unequal magnitudes, 3.6 and 6.8, make the pair difficult for small telescopes. Perhaps you will see it as "pale yellow and lucid blue" as Admiral Smyth did more than a century ago.

WALTER SCOTT HOUSTON

FLARES ON THE MOON?

On August 26, 1955, I was observing the moon with my home-built 6-inch reflector, using an Erfle eyepiece and Goodwin Barlow lens which gave a magnification of 200x and a 20-minute field. At 7:51 p.m. CST, while examining the neighborhood of the Apennines, I saw on the dark portion of the moon a bright flare that remained visible for about 35 seconds. It appeared roughly as bright as a 2nd-magnitude star does to the naked eye. The terminator region of the moon had been under survey for about an hour, and I am certain that the flare was not present for many seconds before I first saw it.

The position of the flare, as estimated in terms of the diameter of the field of view, was in the neighborhood of the Carpathian Mountains. This seemed to be too far inside the dark portion of the moon for the object to have been an isolated mountain peak catching the sunlight. The flare remained fairly steady in brightness, fading only slightly before it abruptly disappeared.

Reports from other observers who were observing the moon at this time would be of interest.

K. E. McCORKLE
1564 Alta Vista
Memphis, Tenn.

Shortly after sunrise on September 8, 1955, I was looking at the moon, high in the sky, through a small 20x telescope. My attention was directed to the Taurus Mountains at the western edge of Mare Serenitatis when, at 7:35 a.m. EDT, I saw two distinct flashes of light, about a quarter second apart, that seemed to come from the edge of these mountains.

There appeared to be nothing that could have caused reflections in my telescope. The sun was hidden behind trees at the time, and there were no aircraft in the sky.

W. C. LAMBERT
2506 S. 10th St.
Ironton, Ohio

SUNSPOT NUMBERS

August 1, 23, 25: **2,** 10, 20: **3,** 5, 16: **4,** 3, 0: **5,** 25, 26: **6,** 43, 46: **7,** 48, 61: **8,** 58, 77: **9,** 78, 83: **10,** 78, 87: **11,** 76, 85: **12,** 70, 77: **13,** 53, 77: **14,** 45, 60: **15,** 32, 44: **16,** 30, 28: **17,** 12, 16: **18,** 15, 10: **19,** 14, 13: **20,** 16, 17: **21,** 19, 22: **22,** 20, 23: **23,** 11, 23: **24,** 11, 14: **25,** 16, 11: **26,** 26, 26: **27,** 54, 40: **28,** 55, 54: **29,** 59, 55: **30,** 61, 49: **31,** 75, 62. Means for August: 36.8 American: 40.2 Zurich.

Above are given the date, the American number, then the Zurich number. These are observed mean relative sunspot numbers, the American computed by D. W. Rosebrugh from AAVSO Solar Division observations, the Zurich numbers from Zurich Observatory and its stations in Locarno and Arosa.

Harry L. Bondy, chairman of the AAVSO Solar Division, has supplied the following information on the American sunspot data. The American relative sunspot number is essentially the same relative sunspot number devised in 1848 by R. Wolf, of Zurich, and widely used

since as an index of solar activity. Wolf's formula for the daily spot number **R** is

$$\mathbf{R} = \mathbf{k}(10\mathbf{g} + \mathbf{f}),$$

where **g** is the total number of sunspot groups visible (isolated single spots also count as groups), and **f** is the number of individual spots that show umbrae. The statistical factor **k** takes into account the size of telescope used and the peculiarities of the observer; it allows his observations to be reduced to a standard scale.

The combination of the results of different observers to form the American relative sunspot numbers follows a statistical method worked out by A. H. Shapley, and described by him in the *Publications* of the Astronomical Society of the Pacific, February, 1949, page 13.

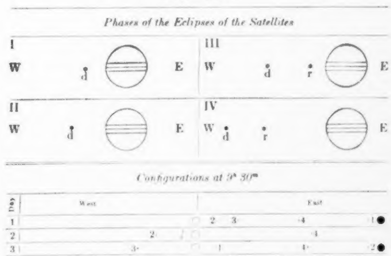
The American numbers printed in this department are final ones. On the other hand, the Zurich numbers are provisional, based on observations at Zurich, Locarno, and Arosa only. At the end of each year, they are modified to form final sunspot numbers, in which data from other stations is incorporated.

JUPITER'S SATELLITES

The configurations of Jupiter's four bright moons are shown below, as seen in an astronomical or inverting telescope, with north at the bottom and east at the right. In the upper part, *d* is the point of disappearance of the satellite in Jupiter's shadow; *r* is the point of reappearance.

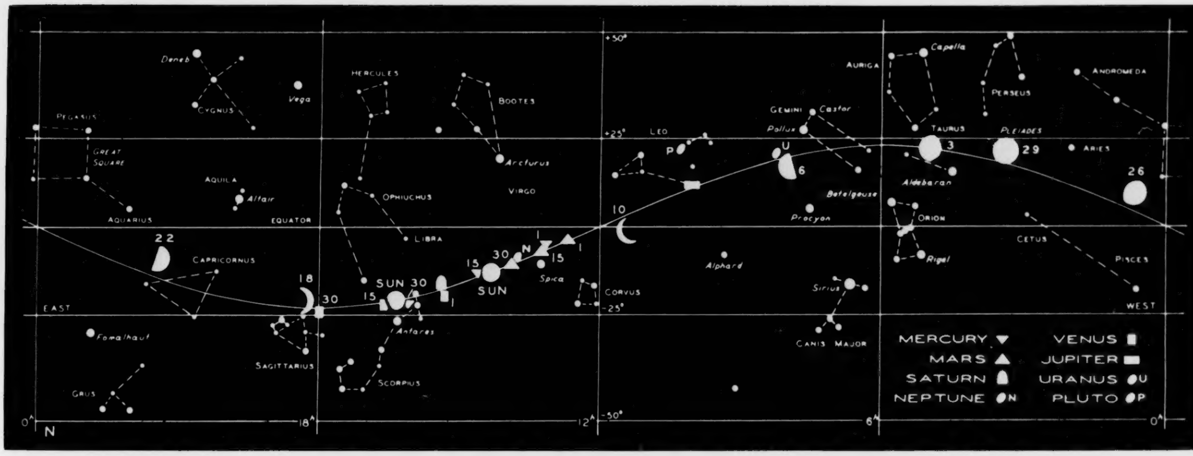
In the lower section, the moons have the positions shown for the Universal time given. The motion of each satellite is from the dot toward the number designating it. Transits over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. The chart is from the *American Ephemeris and Nautical Almanac*.

NOVEMBER



UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Mercury continues as a morning object all November, and can be viewed the first half of the month. During the first week, the planet rises $1\frac{1}{2}$ hours before the sun, and shines at magnitude -0.6.

Venus may be seen low in the southwestern sky shortly after sunset. On the 15th, this brilliant planet sets one hour after the sun, and its telescopic disk appears 95 per cent illuminated, barely distinguishable from full phase.

Moon. There will be a partial lunar eclipse on November 29th for observers in Europe, Africa, and Asia, from 16:21.4 UT to 17:37.4. At mid-eclipse, one eighth of the moon's diameter will be covered by the umbra.

Mars rises $2\frac{1}{2}$ hours before the sun in midmonth, but will be of little interest telescopically till later next year. The red planet, now 2nd magnitude, travels rapidly eastward in Virgo.

Jupiter arrives at western quadrature with the sun on November 23rd, and may be seen rising in the east just before midnight, local time. Moving slowly eastward in Leo, Jupiter passes 21′ north of Regulus on the 8th. Telescopically, the Jovian disk appears 36″.6 in equatorial diameter on the 15th.

Saturn is in conjunction with the sun on November 16th, and hence is not visible this month.

Uranus can be seen in binoculars in the late evening. Now a 6th-magnitude object in Cancer, the planet begins retrograde motion on the 8th.

Neptune may first be seen in the morning sky at the end of November. Mars can be used to help find 8th-magnitude Neptune when they are in conjunction on the 28th. Neptune will be 54′ north of Mars then, and visible in good binoculars.

E. O.

VARIABLE STAR MAXIMA

November 5, R Aurigae, 050953, 7.8; 7, RS Scorpii, 16484**4**, 6.8; 7, W Lyrae, 181136, 8.0; 14, RR Sagittarii, 194**929**, 6.6; 18, R Leonis Minoris, 093934, 7.2; 24, T Normae, 153**654**, 7.4; 25, Z Puppis, 072**820b**, 7.9; 26, R Aquarii, 233**815**, 7.3; 28, R Draconis, 163266, 7.6; 30, R Phoenicis, 235**150**, 7.8. December 7, S Pavonis, 194**659**, 7.3.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

MOON PHASES AND DISTANCE

Last quarter	November 6, 21:56
New moon	November 14, 12:01
First quarter	November 22, 17:29
Full moon	November 29, 16:50
Last quarter	December 6, 08:35

	November	Distance	Diameter
Perigee	2, 03^h	224,900 mi.	33′ 01″
Apogee	17, 23^h	252,300 mi.	29′ 26″
Perigee	30, 11^h	222,300 mi.	33′ 24″
	December		
Apogee	15, 07^h	252,600 mi.	29′ 24″

PREDICTIONS OF BRIGHT MINOR PLANET POSITIONS

Parthenope, 11, 9.4. Nov. 9, 4:50.9 +15-58; 19, 4:42.2 +15-40; 29, 4:31.9 +15-25. Dec. 9, 4:21.4 +15-15; 19, 4:12.0 +15-12; 29, 4:05.1 +15-18.

Psyche, 16, 9.1. Nov. 9, 4:59.6 +18-01; 19, 4:52.4 +17-42; 29, 4:43.6 +17-25. Dec. 9, 4:34.5 +17-10; 19, 4:26.0 +16-59; 29, 4:19.2 +16-55.

Eurynome, 79, 9.4. Nov. 9, 5:16.5 +18-01; 19, 5:10.8 +17-13; 29, 5:02.2 +16-27. Dec. 9, 4:52.5 +15-47; 19, 4:43.2 +15-17; 29, 4:36.2 +15-01.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0^h Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.

MINIMA OF ALGOL

November 2, 6:09; 5, 2:58; 7, 23:47; 10, 20:36; 13, 17:25; 16, 14:14; 19, 11:02; 22, 7:51; 25, 4:40; 28, 1:29; 30, 22:18. December 3, 19:07; 6, 15:56; 9, 12:45.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

OCCULTATION PREDICTIONS

Data for the occultation of Kappa Tauri on November 1-2 appeared in the October issue, page 523.

SATURN PHOTOGRAPHS

Having had permission from the director of the Union Observatory to use the 9-inch Grubb visual refractor, I have tried my hand at photography, using a home-made attachment consisting of a Barlow lens, yellow filter, and shutter, with 35-mm. film. The objective was stopped down to six inches.

The enclosed pictures were enlarged from negatives obtained on June 16, 1955, at 18:55 UT (left) and June 22, 1955, at 17:20. The one on the left is a 20-second exposure enlarged about seven times; that on the right, 12 seconds, enlarged 4½ times.

The size of the globe of Saturn on the negatives is one millimeter, and the relatively long exposures, up to 20 seconds, indicate that good pictures can only be secured when the seeing is excellent; so far it has been only fair.

I am a member of the Astronomical Society of South Africa.

JOHN R. BOTHAM
94 Ascot Rd., J. P.
Johannesburg, South Africa

13 VULPECULAE, A NEW DOUBLE STAR

The naked-eye stars have been so thoroughly surveyed for doubles by the Struves, Burnham, Aitken, and others, that it is an unusual event to find a 5th-magnitude star with a hitherto unrecognized companion that can be seen in a 10-inch telescope. In 1953, P. Djurkovics found with the 23½-inch Belgrade refractor that 13 Vulpeculae ($19^h\ 51^m.3$, $+23°\ 57'$) was an easy double, with magnitudes 4.8 and 8.0, position angle 242°, and separation 0.8 second.

Confirming observations have just been published by two French observers, P. Muller with the 19-inch Strasbourg refractor, and P. Couteau with a 15-inch at Nice. Probably the reason the pair was discovered now, and not earlier, is that the companion's orbit is very elongated and the separation is now near its maximum value. There is little if any evidence of change between the measurements made in 1953 and in 1954.

The pair should be readily split by an experienced observer with a good 10-inch telescope.

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NEW BOOKS: Wilkins, *Mysteries of Time and Space*, $3.50; Hoyle, *Frontiers of Astronomy*, $5.00. Write for list. Herbert A. Luft, 42-10 82nd St., Elmhurst 73, N. Y.

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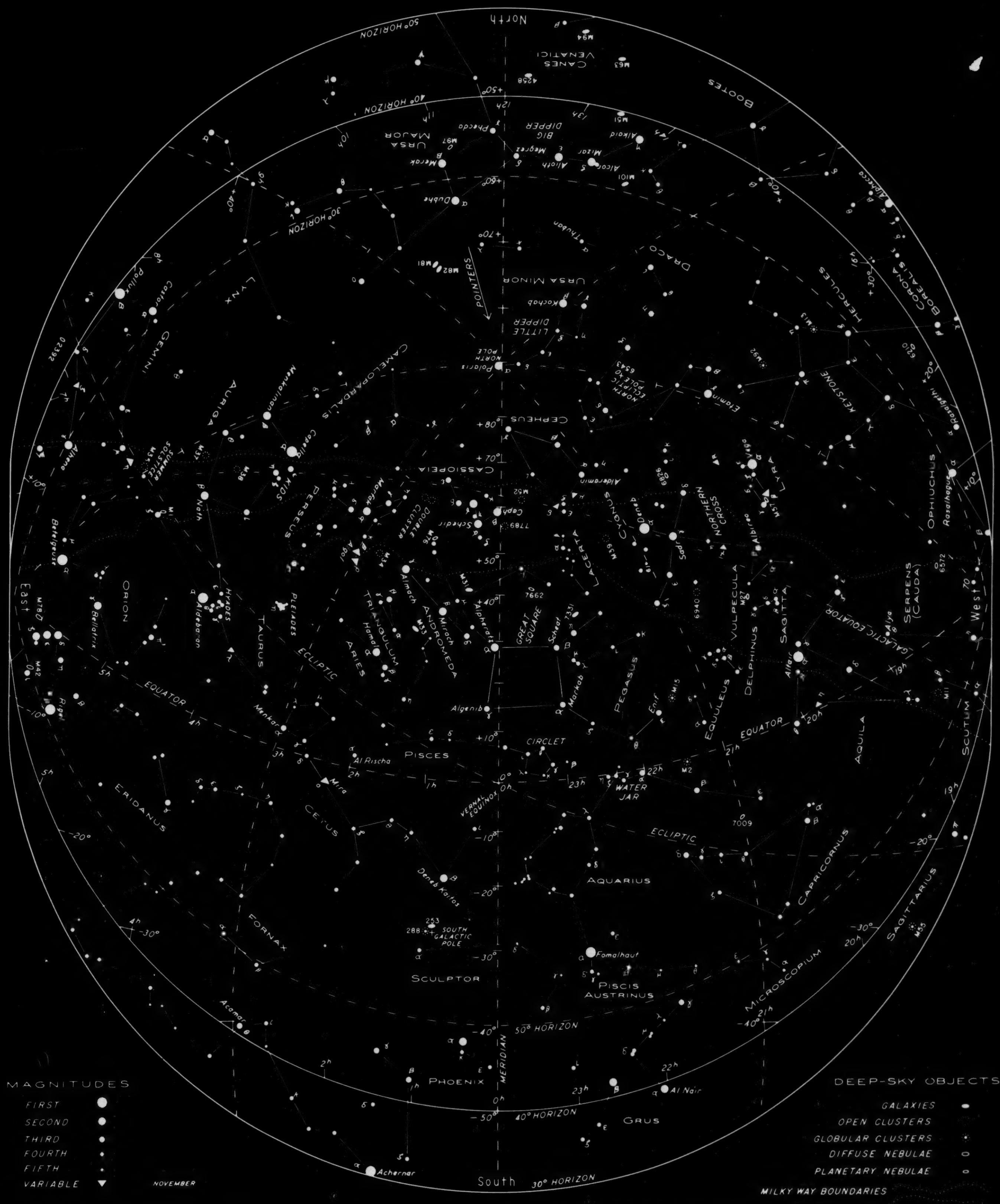
"TARGET: EARTH" is collision geology. This book presents and evaluates evidence of repeated collisions of large meteors with the earth. Authors—Allan O. Kelly and Frank Dachille. 263 pages, $5.00. Target: Earth, Box 335, Carlsbad, Calif.

AXIAL ROTATION AND STELLAR EVOLUTION

(Continued from page 19)

cent—an insignificant amount. But if other processes are at work, for example, a star also loses mass by rotational instability or corpuscular radiation, the original radius may have been much larger than that found by tracing its past history along a Sandage-Schwarzschild track.

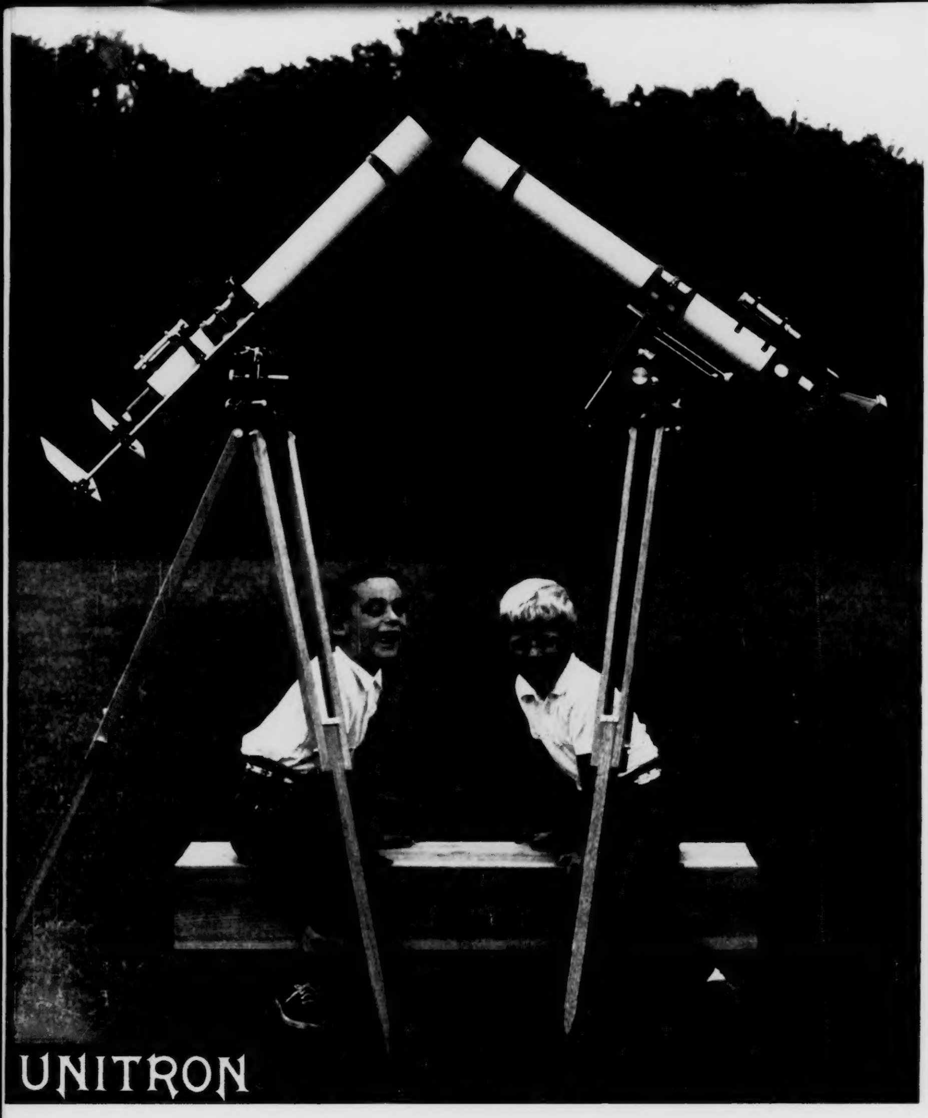
Thus, a subgiant star that now has a small observed rotational velocity may actually have possessed an even smaller velocity when it was on the main sequence, because with its larger initial mass its radius would also have been in excess of that computed with the Sandage-Schwarzschild values. In this case, the computed histograms would show still more *B* stars with rapid rotation, and at first sight the agreement with the present distribution would become worse, not better. But in the distant past these more massive, original stars would belong to earlier spectral classes. A star shown in Fig. 6 as being of class *B* might actually have been an *O*-type star; therefore, we should really compare the computed distribution with the present distribution of the *O* stars. These latter stars are not included in the published papers of Slettebak (though he has recently observed many of them at Mount Wilson and Palomar Observatories). But from the earlier Yerkes work there was some indication that the *O*-type stars indeed show a greater proportion of slowly rotating objects than do the *B* and *A* stars. Slettebak also remarks, "On the main sequence, axial rotation appears to reach a maximum for the middle *B*-type stars." Presumably, the early *B* stars and the *O* stars have, on the average, slower rotations.



STARS FOR NOVEMBER

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of November, respectively; also, at 7 p.m. and 6 p.m. on December 7th and 23rd. For other times, add or subtract ½ hour per week.

For those just beginning constellation study, an easily identified starting point is Cassiopeia, a compact W-shaped group just north of the zenith at chart time. Look also for the Great Square of Pegasus, high in the southern sky in this season.



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See pages 34 and 47.

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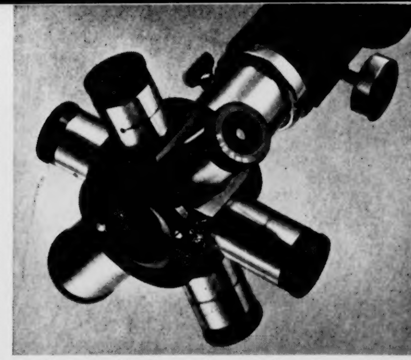
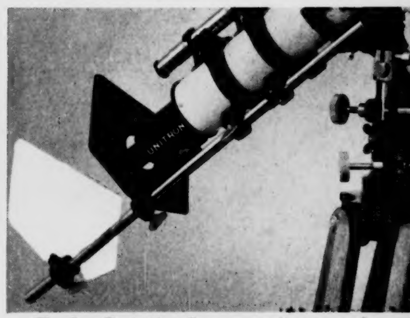
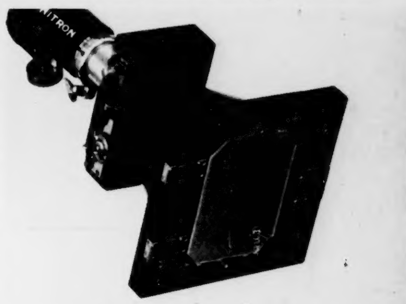


Six magnifications at your fingertips with the UNIHEX Rotary Eyepiece Selector.

With the DUETRON Double Eyepiece, two observers may use the UNITRON together.



The Sun Projecting Screen permits group observation and accurate charting of sunspots.



With Astro-Camera 220, it's easy to photograph the sun, sunspots, the moon, and eclipses.

Use the Erecting Prism System for real closeup views of distant terrestrial objects.

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